

DRAFT REPORT
FEASIBILITY EVALUATION
SOURCE AREA REMEDIATION
Former Buildings 1/36 and 2 Areas
(Revision 1)

Boeing Realty Corporation
 Former C-6 Facility
 Los Angeles, California

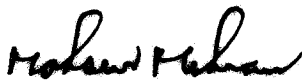
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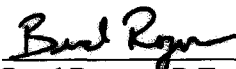
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August 19, 2005

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**Draft Report
Feasibility Evaluation
Source Area Remediation
Former Buildings 1/36 and 2
(Revision 1)
Boeing Realty Corporation
Former C-6 Facility
Los Angeles, California**

Dear Mr. Mossman:

Transmitted herewith is a draft Revision 1 of the Feasibility Evaluation Report for the source area remediation of Boeing Realty Corporation's (BRC's) former C-6 Facility located in Los Angeles, California. The report will be finalized upon receipt and consideration of your review comments. If you have any questions, please do not hesitate to call.

Respectfully submitted,

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MM:db
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1.0 INTRODUCTION

In July 2001, a feasibility evaluation was performed to address deep soil and groundwater remediation at the Boeing Realty Corporation's (BRC)'s Former C-6 Facility (the site) located in Los Angeles, California. Enhanced in-situ bioremediation (EISB) was selected as the preferred remedial option for groundwater. Subsequent to approval from the California Regional Water Quality Control Board, Los Angeles Region (LARWQCB), the initial phases of EISB have been implemented and tested. Based on the initial results of the EISB and because of changes in the regulatory environment and conditions in off-site areas, BRC has initiated the subject feasibility evaluation to address the source areas of the former Buildings 1/36 and 2. The remainder of this section presents the objectives of the feasibility evaluation, the impacted media, the chemicals of potential concern, and the report organization.

1.1 OBJECTIVE AND APPROACH

The objective of this feasibility evaluation is to support the selection of the most appropriate remedial alternative(s) based on effectiveness, implementability, and cost for reducing the concentrations of the chemicals of concern (COCs) at the source areas within the former Buildings 1/36 and 2 areas. To achieve this objective, the following factors were considered and evaluated:

- Site data developed after the first feasibility evaluation dated July 18, 2001
- Results of the site remediation including the EISB
- Characteristics of the facilities adjacent to the site and associated regulatory activities
- Access restrictions imposed by new structures, owners, and tenants
- Anticipated activities at the Del Amo and Montrose Superfund sites

1.2 REMEDIATION TARGET ZONES

The hydrogeologic units that are subject to source area remediation include the B-Sand, the C-Sand, and the Gage Aquifer beneath the site. The B-Sand extends from approximately 65 feet, where groundwater is encountered, to 90 feet below ground surface (bgs). The C-Sand extends from approximately 90 to 120 feet bgs. The Gage Aquifer extends from approximately 150 to 200 feet bgs. The source area for the B-Sand is defined as the area containing greater than 5,000 µg/l of trichloroethene (TCE). The source area in the C-Sand is defined as the area containing greater than 1,000 µg/l of TCE. The extent of impact of site chemicals on the Gage Aquifer is currently unknown. However, because of recent detection of TCE in wells adjacent to

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the site and the anticipated future impact of remedial activities at the Del Amo and Montrose sites, this feasibility evaluation also addresses the Gage Aquifer .

1.3 CHEMICALS OF CONCERN

The historical groundwater quality data show the presence of several volatile organic compounds (VOCs) and oxygenated compounds at the site. However, in terms of concentration and distribution, TCE and 1,1-dichloroethene (1,1-DCE) are the most prevalent compounds detected. Therefore, these two constituents are considered as the key COCs for this feasibility evaluation. In addition to VOCs, hexavalent chromium has also been detected at the site. However, the source of hexavalent chromium is from off-site areas to the west of the site and therefore, is not considered a COC for this feasibility evaluation.

1.4 REGULATORY FRAMEWORK

The LARWQCB has been the oversight agency for the site since investigations began and remains as such to date. The LARWQCB has also jurisdiction over the facilities located to the east, referred to as East Normandie Sites. The department of Toxic Substances Control (DTSC) is the oversight agency for International Light Metals (ILM) located to the west of the site. The U.S. Environmental Protection Agency (U.S. EPA) is the oversight agency for the Montrose and Del Amo Superfund sites. Although the LARWQCB is the oversight agency for the Former C-6 Facility, BRC has complied with U.S. EPA's request to complement the existing database. However, BRC is committed to continue all investigation and remediation activities under the jurisdiction of the LARWQCB.

1.5 REPORT ORGANIZATION

Section 2.0 presents the hydrogeologic and groundwater quality characteristics of the site. Section 2.0 also provides a brief description of the conditions of the adjacent facilities to the extent that may affect this feasibility evaluation. A summary of interim remedial measures is presented in section 3.0. The screening and evaluation of remedial technologies is presented in Section 4.0. The selected remedial alternatives are presented in Section 5.0.

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2.0 CHARACTERISTICS OF THE SITE AND VICINITY

This section summarizes the characteristics of the site pertinent to the development of the feasibility evaluation. In addition, this section provides relevant information for the facilities located adjacent to or in the vicinity of the site.

2.1 SITE CHARACTERISTICS

Relevant site characteristics include site location and setting, history, geology, hydrogeology, soil quality, and groundwater quality. Other factors considered in selecting the remedial alternatives include the existing infrastructure, current understanding of past remedial measures, plans for additional development of the site, and environmental conditions of the facilities located in the vicinity of the site.

2.1.1 Site Location and Setting

The site is located at 1451 West Knox Street (formerly 19503 South Normandie Avenue) in Los Angeles, California. The site location is shown in Figure 1. The site occupies approximately 156 acres and it is bounded by 190th street to the north; Normandie Avenue to the east; Montrose Chemical Corporation (Montrose), Jones Chemical to the south; and ILM to the west. This description represents the footprint of the site prior to the sale of any portion of the property. A plan of the site and vicinity is shown in Figure 2.

The site is surrounded by several properties with documented groundwater contamination. Immediately to the east, there are several facilities referred to as East Normandie Sites which are currently under investigation with LARWQCB oversight. Also to the east and to the south of the site, the Montrose/Del Amo sites have been investigated extensively (Figure 2). Jones Chemical to the south of the site and the ILM property to the west of the site have groundwater contamination plumes originating from their respective operations. The most common contaminant among all properties investigated is TCE. The principal contaminants at the East Normandie Sites are the chlorinated VOCs. The principal contaminants present at the Del Amo site are benzene and TCE. The primary contaminant present at the Montrose site that extends onto the Former C-6 Facility is chlorobenzene. The primary contaminants present at the ILM site that extend onto the Former C-6 Facility are TCE and hexavalent chromium.

Based on a joint feasibility study conducted for the Montrose and Del Amo Superfund sites (CH2M Hill, May 18, 1998), the U.S. EPA has issued a Record of Decision (ROD) dated March 1999. Among other things, the ROD requires implementation of a groundwater extraction/injection system. Although the remedial design of the system has not formally started, large-scale pilot tests are currently being planned. According to U.S. EPA, these long-term pilot tests are intended to be implemented in phases toward achieving the full-scale remedy.

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Therefore, the potential effects of large-scale pilot tests on groundwater conditions of the site need to be considered in this feasibility evaluation.

2.1.2 Site History

Prior to 1940, the site was reportedly farmland. Between 1940 and 1952, industrial uses of the site included aluminum and steel production. From 1952 to 1992, portions of the site were used for the manufacture of aircraft and aircraft parts. A limited amount of assembly and activities related to warehousing continued through mid-2000 when business operations ceased. For redevelopment purposes, the site was divided into four parcels, A, B, C and D (Figure 2). Site redevelopment is currently ongoing with plans for completion in 2006.

Soil and groundwater investigations at the site began in 1987. Since then, numerous borings have been drilled and samples have been collected to assess the potential environmental impact of the site operations on soils underlying the site. A total of 50 groundwater monitoring wells have been installed to define the hydrogeologic and water quality characteristics of the site. Seventeen of the 48 wells have been abandoned as a result of redevelopment activities. Table 1 presents the groundwater monitoring well construction details of the existing wells.

In addition to the monitoring wells, numerous amendment points or wells have been installed as part of the implementation of the EISB. All monitoring and amendment wells are perforated either in the B-Sand or the C-Sand. Two wells have recently been installed in the Gage Aquifer but the results of water quality analysis of these wells are not yet available.

2.1.3 Regional Geology and Hydrogeology

The geology and hydrogeology of the region surrounding the site are reported by the California Department of Water Resources. The site is located on the Torrance Plain at an elevation of about 50 feet above mean sea level (MSL). The DWR defines this area as a Pleistocene-age marine surface and subdivision of the West Coast Basin/Costal Plain of Los Angeles and Orange Counties. The groundwater basins that have been defined in the area are shown in Figure 3.

Regional topography is generally flat with an eastward ground surface slope of about 20 feet per mile (less than 0.5 percent). Surface drainage is generally toward the Dominguez Channel, about a mile to the east which flows southeast toward the Los Angeles and Long Beach harbors in San Pedro Bay. The West Coast Basin includes a thick sequence (up to 13,000 feet) of marine and continental sediments (Miocene to Recent). The principal hydrogeologic units are the Lakewood Formation and the San Pedro Formation. A summary of the various regional geologic formations is shown below:

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Formation	Hydrostratigraphic Unit	
Lakewood Formation (Upper Pleistocene)	Bellflower Aquitard	Upper Bellflower Aquitard (UBA)
		Middle Bellflower Sand (MBFB, MBFM, MBFC)
		Lower Bellflower Aquitard (LBF)
	Gage Aquifer	
San Pedro (Lower Pleistocene)	Gage Lynwood Aquitard (GLA)	
	Lynwood Aquifer (LYNWOOD)	
	Unnamed Aquitard	
	Silverado Aquifer	

According to DWR (1961), the Lakewood Formation includes all of the upper Pleistocene sediments in the Los Angeles Coastal Plain area, which in the site area would include the Semi-Perched aquifer, the Bellflower Aquitard and the Gage Aquifer. Based on correlations of site stratigraphic data with the data from adjacent sites, it appears that the Semi-Perched aquifer is absent at the site. The Bellflower Aquitard is a heterogeneous mixture of continental, marine, and wind-blown sediments, mainly consisting of clays with sandy and gravelly lenses (DWR, 1961). The base of Bellflower Aquitard is about 100 feet below MSL or about 150 feet bgs in the site area. The Gage Aquifer is the water-bearing zone of fine to medium sand and gravel confined by the Bellflower Aquitard. The Gage aquifer is reported to be about 40 to 50 feet thick in the site area.

The Lakewood Formation is underlain by the Lower Pleistocene San Pedro Formation, which extends to about 1,000 feet bgs in the site area. Major water-bearing zones within the San Pedro formation are the Lynwood aquifer and the Silverado aquifer. These are reported to be about 300 and 500 feet bgs, respectively, in the site area (DWR, 1961).

Groundwater management within the West Coast Basin has been under the control of a Watermaster since the mid 1940s to minimize impacts from aquifer over-pumping and the resulting water quality degradation due to saltwater intrusion and industrial and agricultural activities. All groundwater withdrawals must be approved by the Watermaster. Currently, two active reinjection programs are operating in the basin. The first is the West Coast Basin Barrier wells located just inland of Santa Monica Bay, 6 miles west of the Former C-6 Facility. The second reinjection program is the Dominguez Gap Barrier located in the Wilmington/Carson area along Sepulveda Boulevard. Together, these programs inject approximately 20,000 acre-feet per year of imported water back into the basin. This injection has caused water levels in the basin to recover approximately 20 feet or more in the Upper Pleistocene and Recent aquifer since their historical lows in the late 1960s. Regional groundwater flow in the upper water-bearing units is generally east-southeast.

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Historically, three wells at the Former C-6 Facility have been registered with the West Coast Basin Watermaster. These water rights were leased by the Douglas Aircraft Corporation from the U.S. Navy on a long-term basis. All three wells, completed within the Gage aquifer, have been abandoned in accordance with state and local guidelines.

2.1.4 Site Geology and Hydrogeology

2.1.4.1 Site Geology

Soil borings and groundwater monitoring wells drilled at the site have encountered the Lakewood Formation. The majority of the monitoring wells extend to approximately 90 feet bgs. The upper 20 to 50 feet are predominantly silts and clays that increase in thickness to the east. A sandy zone underlies the fine-grained soils and dips to the east. This zone is generally 80 to 100 feet thick and contains both continuous and discontinuous layers of fine-grained sediments. The sandy unit is underlain by another fine-grained zone at approximately 110 to 120 feet bgs. Two cross-sections were developed to depict the site stratigraphy, and are oriented as shown in Figure 4. The cross-sections presented in Figures 5 and 6 depict the following stratigraphic units:

- Upper Bellflower Aquitard (UBF)
- Middle Bellflower Sand (MBFB)
- Middle Bellflower Mud (MBFM)
- Middle Bellflower Sand (MBFC)
- Lower Bellflower Aquitard (LBF)
- Gage Aquifer

The relatively fine-grained Upper Bellflower Aquitard (UBF) is continuous across the area but thins to the northwest and southwest. The UBF is comprised of laminated to massive yellowish brown muds with local sands and fossiliferous zones. The UBF is found at the surface beneath the site and is approximately 25 feet thick.

The Middle Bellflower Sand is a massive, light yellowish brown, fine to medium sand with local muddy zones. An extensive mud layer referred to as the Middle Bellflower Mud (MBFM) locally interrupts this sand. Where divided, the sand subunits are referred to as the B-Sand (MBFB) and C-Sand (MBFC). The MBFM is discontinuous across the area and is comprised of laminated silts and layered silts and very fine sands. Deeper borings at the former ILM facility and the site do not always encounter the MBFM. The MBFM is 25 to 40 feet thick and is found at different depths across the site, ranging from an approximate minimum depth of 40 feet bgs to an approximate maximum depth of 80 feet bgs. The MBFC is found at approximate depths of 65 to 90 feet bgs in the western portion of the site to 90 to 120 feet bgs in the eastern portion of the site.

The fine-grained Lower Bellflower Aquitard (LBF) appears to be continuous across the area. It occurs at an approximate depth of 110 to 120 feet bgs and ranges in thickness from 10 to 25 feet.

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The LBF separates the Bellflower Sands from the underlying Gage Aquifer. The Gage Aquifer in the site vicinity is predominantly sand and ranges in thickness from 40 to 50 feet.

2.1.4.2 Site Hydrogeology

Groundwater at the site is encountered at depths of 60 to 70 feet bgs in the relatively permeable sediments of the Bellflower Aquitard. Wells installed in the Middle Bellflower Aquitard are perforated either in the B-Sand or the C-Sand. Table 1 shows the construction details of the wells including the perforated intervals.

Water levels in the basin have been rising, primarily because of Watermaster's management policies. Maximum elevation of the water tables appears to have been reached in 1999. Since then, slight basin-wide decreases have been noted. As shown in Figures 7 and 8, the water levels at the site have risen several feet from 1987 to 1999. The hydrographs show that these wells have responded uniformly to the regional conditions.

Figure 9 presents the groundwater contour map using the 2004 water level data (for the water table/B-Sand). The direction of groundwater flow beneath the Former C-6 Facility is to the south, while at ILM, the groundwater flow direction is primarily to the east/southeast toward the Former C-6 Facility. To the northwest and east of the site, the apparent groundwater flow direction is to the southwest. Historic groundwater flow directions and gradients in the southern portion of site are expected to have been influenced by water injection activities at the Montrose property. Based on a review of historical groundwater elevation data, there is no significant downward gradient from the B-Sand to the C-Sand.

As shown in Figure 10, the groundwater flow direction in the C-Sand beneath the site and in off-site areas is to the southeast. In the Gage Aquifer, as shown in Figure 11, the groundwater flow direction is to the southeast.

Vertical groundwater gradients are minimal, variable, and generally downward. The observed gradients are not expected to substantially alter groundwater transport at the site, which is predominantly lateral in nature. From the Del Amo Study Area wells, comparison of reported water levels of various hydrogeologic units shows generally a similar downward gradient from the upper units to the lower units, ranging from 0.0027 ft/ft to 0.187 ft/ft. A limited number of locations have exhibited an upward gradient. The hydraulic parameters for the B-Sand and C-Sand are summarized in Table 5. The horizontal hydraulic conductivity of the Gage Aquifer is reportedly 36 feet per day (CH2M Hill, October 2004).

2.1.5 Nature and Extent of VOCs in Groundwater

Groundwater quality investigations have shown the presence of chlorinated VOCs and inorganic constituents in the Middle Bellflower Sand beneath the site. The historical data collected at the adjacent Del Amo/Montrose properties demonstrate the presence of chlorinated and non-chlorinated VOCs and certain other chemical parameters in aquifers underlying those facilities.

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The most recent comprehensive set of groundwater monitoring for the site and vicinity was performed mostly during January through April 2004. This includes data from the Former C-6 Facility, ILM, Montrose, Del Amo, Paccar, American Polystyrene, and Ecology Control Industries. The significant findings for each water-bearing zone are summarized below.

2.1.5.1 B-Sand Water Quality

The highest concentrations of chlorinated VOCs detected in groundwater at the site include TCE, and 1,1-DCE. The lateral distributions of these compounds in the WaterTable/B-Sand at the site and vicinity are shown in Figures 12 and 13. There appears to be possible TCE sources at each of the facilities shown in Figure 12. The highest concentration of TCE was detected in Well MW-03T at the Paccar facility at a concentration of 18,000 µg/l. Well P-20 at ILM had the next highest concentration of TCE of 6,600 µg/l. At the site, the highest TCE concentration (5,500 µg/l) was detected in Well TMW-02, located in the Building 1/36 source area. Montrose Well MW-06, located near the southern boundary of Jones Chemical contained 1,100 µg/l of TCE. At Del Amo, the highest TCE concentration (339 µg/l) was detected in Well SWL0051, located south of Del Amo site boundary along 204th street. Elevated TCE concentrations observed along the western boundary of the site suggest a TCE source originates on the ILM property. Further, the absence of 1,1-DCE in the plume located on a western portion of the site adjacent to ILM property suggests that the detected TCE in this area does not originate from the former Buildings 2 and 1/36 areas.

The highest concentrations of 1,1-DCE at the site originate in the vicinity of the Building 1/36 source area (Figure 13). Well TMW-02 contained 19,000 µg/l of 1,1-DCE. The majority of the 1,1-DCE is limited to the Building 1/36 source area and does not appear to have migrated offsite. The only significant detections of 1,1-DCE offsite were found in Montrose Well MW-06, located near the southern boundary of Jones Chemical and ILM Well P-17, located near the center of the ILM property at concentrations of 320, and 340 µg/l, respectively. The majority of the offsite wells did not contain 1,1-DCE.

Hydropunch data from the 2001 site-wide investigation along with the 2004 monitoring well data were utilized to generate TCE plumes for the B-Sand. Figure 14 shows the Building 1/36 and Building 2 source areas represented by purple shading depicting the greater than 5,000 µg/l plumes. It appears that the majority of the TCE is contained onsite. In general, the concentrations of TCE in the B-Sand have remained stable or have shown a slight decreasing trend. Appendix A presents TCE concentrations versus time in various wells near the Building 1/36 and Building 2 source areas and site boundaries. At the former Building 2 area, TCE and 1,1-DCE concentrations have not changed significantly while at the former Building 1/36 area there appears to be a decreasing trend. TCE concentrations measured in Well DAC-P1, located at the eastern boundary of ILM, are relatively constant.

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However, the most recent data for these wells show detectable concentrations of *cis*-1, 2-DCE ranging from 23 to 48µg/ℓ which is an indication that reductive dechlorination is occurring in this area of the plume, although at a slower rate than found within the Building 1/36 plume. This area of the site also does not exhibit detectable concentrations of compounds that serve as potential electron donors (i.e., toluene, natural organic matter) to enhance intrinsic reductive dechlorination processes. As a result, BRC installed an EISB system in this portion of the site in 2002. Several injection attempts have been made with food grade electron donors (molasses, lactate) since installation that may now be altering the subsurface geochemistry in this area.

2.1.6.3 Southern Site Boundary/Montrose Plume

The partially-depleted dissolved oxygen concentrations and oxidation/reduction potentials in this area (Wells TMW-11 and XMW-09) indicate that some anaerobic activity may be occurring; however, the lack of *cis*-1,2-DCE does not confirm the process. The potential for cometabolic biodegradation of TCE and DCE exists at the southern site boundary based on the presence of chlorobenzene (a possible cometabolite) near the southern boundary and at the adjacent Montrose site.

2.2 ADJACENT SITES CONDITIONS

The site is surrounded by several facilities with documented release of contaminants into the subsurface environment. Available data demonstrate that some of these contaminants have affected the subsurface conditions of the Former C-6 Facility. Furthermore, future investigation and remediation of certain facilities may also impact the site conditions. Therefore, this section presents a brief description of each of these facilities regarding the current environmental investigation and remediation activities and regulatory status of facilities located adjacent to or in the vicinity of the site. These facilities are shown in Figure 2 and are listed below.

- Del Amo Site
- Risto Los Angeles
- Ecology Control Industries
- American Polystyrene Corporation
- PACCAR Inc.
- Mighty USA
- Redman Equipment
- Montrose Chemical Corporation (Montrose)
- Jones Chemical
- International Light Metals (ILM)

For each of these sites, regulatory oversight is provided by the United States Environmental Protection Agency, (EPA), Department of Toxic Substances Control (DTSC), or California Regional Water Quality Control Board, Los Angeles Region (LARWQCB). Figure 2 presents locations and the principal COC's for each facility. Figures 19, 20, and 21 show the distribution

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2.1.5.2 C-Sand Water Quality

As discussed above, the most comprehensive sampling within the site and vicinity was conducted in early 2004. Distribution of TCE and 1,1-DCE in C-Sand groundwater is presented in Figures 15 and 16, respectively. The highest concentration of TCE was detected in Well SWL0029 at a concentration of 3,100 µg/l. This well is located along the property boundary of Paccar and Del Amo. At the site, TCE ranged in concentration from 125 µg/l in Well CMW001, located near the southwest corner of the site, to 1,600 µg/l in Well MWC015, located near the Building 2 source area in the middle of the site. Detected concentrations of TCE at Montrose ranged from 170 to 710 µg/l. ILM Well P-16C, located in the center of the site, contained 700 µg/l of TCE. ILM Well BL-11C, located along the southwestern portion of the site contained 170 µg/l of TCE. The TCE in this well is believed to be from ILM based on the groundwater flow direction and its location relative to the Building 1/36 and Building 2 source areas.

The distribution of 1,1-DCE appears to be limited to the site, with the exception of 28 µg/l detected in ILM Well P-16C (Figure 16). The detected concentrations at the site ranged from 3.3 to 130 µg/l. This distribution may be misleading as many of the detection limits in the off-site wells were as high as 500 µg/l.

To further examine the distribution of TCE in the C-Sand at the site, hydropunch data from the 2001 site-wide investigation along with the 2004 monitoring well data were utilized to generate TCE plumes for the site. Figure 17 shows the Building 1/36 and Building 2 source areas represented by the greater than 1,000 µg/l plumes. It appears that the majority of the TCE is contained onsite although TCE was detected at 540 µg/l in Well CMW002, located south of Francisco Street on Parcel D in the southwest corner of the site. As shown in Appendix A, concentrations of TCE and 1,1-DCE in C-Sand wells show a decreasing trend. This may be attributed to the presence of oxygenated and aromatic compounds that enhance dechlorination of VOCs.

2.1.5.3 Gage Aquifer Water Quality

There is no Gage Aquifer water quality data available for the site. However, off-site wells have shown TCE at maximum concentrations of 490 µg/l. The distribution of TCE in the Gage Aquifer is shown in Figure 18. BRC has recently installed two wells in the Gage Aquifer along the eastern site boundary. Figure 18 will be updated upon completion of the Gage Aquifer characterization.

2.1.6 Natural Attenuation Monitoring Data

As defined by EPA's Office of Solid Waste and Emergency Response (OSWER) directive, Monitored Natural Attenuation (MNA) relies upon a variety of physical, chemical, or biological processes that, under favorable conditions, act without human intervention to reduce the mass, toxicity, mobility, volume, or concentration of contaminants in soil or groundwater. These in-situ

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processes include biodegradation, dispersion, dilution, sorption, volatilization, radioactive decay, and chemical/biological stabilization, transformation, or destruction of contaminants.

Intrinsic biodegradation processes, primarily reductive dechlorination, are active in portions of the site. The degree to which the biodegradation processes act to affect plume attenuation/migration appears to be limited by the amount of organic carbon (electron donor) present. The lines of evidence that support these conclusions are summarized as follows:

- The existence of bio- and non-biodegradation daughter products (mainly cis-1,2-DCE and 1,1-DCE respectively);
- Additional geochemical data, including dissolved oxygen depletion and negative oxidation/reduction potential (ORP) measurements, indicate that conditions conducive to anaerobic reductive dechlorination currently exist in some areas of the site. These parameters have been measured during routine groundwater sampling events beginning in 2002.
- In January/February 2001, a selected number of wells located upgradient, within, and downgradient of source areas within the aquifer were monitored to further assess the degree of natural attenuation across the site.

Characteristics of each of the three areas of the combined plumes (Building 1/36, Building 2, and southern portion/Montrose) where data were collected are discussed below.

2.1.6.1 Building 1/36 Plume

Low dissolved oxygen concentrations (Table 2) and ORP measurements (Table 2) in the vicinity of Wells WCC-03S and TMW-2 indicate the presence of anaerobic conditions that are conducive to reductive dechlorination processes. The presence of biodegradation daughter product cis-1,2-DCE (2,400 µg/ℓ in Well WCC-3S during March 2004 sampling event) further supports that natural attenuation (reductive dechlorination) of TCE is occurring in this area of the site. Toluene is present in this portion of the plume and appears to be acting as an electron donor and enhancing the reductive dechlorination of site contaminants. Ketones (MEK and MIBK) were also historically present and could also serve as electron donors. The relatively high total organic carbon (TOC) concentrations measured in 2001 in the wells in this portion of the plume, compared with background levels, indicate the presence of this anthropogenic carbon. The low concentrations of alternate electron acceptors (nitrate, sulfate) and the presence of ferrous iron also support the presence of the anaerobic conditions necessary for reductive dechlorination.

2.1.6.2 Building 2 Plume

Elevated dissolved oxygen levels and oxidation/reduction potentials have been observed in wells located within the vicinity of the former Building 2 (Wells MWB012, TMW-04, and TMW-05).

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of the plumes for the water table/B-Sand, C-Sand, and Gage Aquifer, respectively. A brief description of the facilities with potentially significant impact on the site is presented below.

2.2.1 Del Amo Site

A 270-acre synthetic rubber facility, known as the Del Amo Site, was operated by several companies including Shell Oil Company and Dow Chemical Company from 1942 to 1972. Environmental investigations at this facility have shown that the principal COCs are benzene and chlorinated solvents. In September 1999, USEPA issued a joint Record of Decision (ROD) for the Del Amo and Montrose sites. The ROD calls for containing the non-aqueous phase liquids (NAPLs) rather than cleaning up the aquifers to drinking water standards. The ROD also requires implementation of a pump-and-treat system to contain the dissolved plumes. The respondents for this site are primarily Shell Oil Company and the General Services Administration.

The Del Amo site is a Superfund site and US EPA is the oversight agency. EPA considers the Del Amo and Montrose sites to be a joint site regarding ground water investigation and remedial actions. Recently, US EPA has requested the LARWQCB and the owners/operators of facilities adjacent to the Del Amo and Montrose sites to further characterize the water quality of the water-bearing zones beneath these sites with emphasis on the Gage aquifer and the C Sand. In response, BRC has installed two wells in the Gage Aquifer. Initial remedial design is expected to continue concurrent with additional site characterization until mid 2005. Large-scale groundwater extraction pilot tests are anticipated to extend to 2007 as part of the overall remedy. US EPA intends to implement the groundwater remedy in phases.

2.2.2 American Polystyrene Corporation

American Polystyrene Corporation produced polystyrene by mixing a styrene polymer and mineral oil. The principal COCs are TCE, PCE, methylene chloride, and styrene. According to LARWQCB's September 24, 2004 letter, TCE and PCE have been detected in on-site soil up to 46,000 and 2,400 ug/kg, respectively. American Polystyrene has requested to "be removed from all further ground water monitoring, assessment and/or remediation requirements." A response from LARWQCB was not available for review.

2.2.3 PACCAR (Former Trico Industries)

Hazardous materials used at this facility included paints, paint thinners, and various types of lubricating and hydraulic oils. Elevated concentrations of diesel fuel, TCE, PCE, TCA, and 1,2-DCA have been detected in soil and groundwater. The borings drilled near the northern boundary of the site have shown elevated levels of TCE and PCE at concentrations up to 7,000 ug/kg. PACCAR has requested closure for soils in the southern portion of the site and has recommended enhanced bioremediation to remediate the soil near the northern site boundary.

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2.2.4 Montrose Chemical

The Former Montrose Chemical facility is located at 20201 S. Normandie Avenue, Torrance, California. It is located immediately adjacent to and south of the Former C-6 Facility. Montrose operated a DDT-manufacturing plant at this 13-acre property from 1947 to 1982. Chemicals of concern in soil and groundwater include DDT, chloroform, chlorobenzene, benzene, para-chlorobenzene sulfonic acid (pCBSA), and chlorinated VOCs. In September 1999, the USEPA issued a joint Record of Decision for the Del Amo and Montrose sites. Recent activities at this facility include installation of Gage Aquifer wells, installation of extraction/injection wells, planning for drilling a large number of borings and wells, preparation for extraction/injection pilot tests at flow rates of up to 200 gpm, and reporting.

2.2.5 International Light Metals

International Light Metals (ILM) is located at 19200 S. Western Avenue, bordered to the north by W. 190th Street and to the east by the Former C-6 Facility. This 67-acre property was an industrial metal processing company from the beginning of World War II to 1992. Its operations included manufacturing and processing aluminum and titanium products. The principal chemicals included VOCs such as TCE and chromium. The wastes of their operation included spent sulfuric acid and sodium hydroxide, waste oils, spent TCA, acid and caustic sludges, spent petroleum solvents, and PCBs. High concentrations of TCE and hexavalent chromium have been detected at this facility. ILM groundwater quality data demonstrate that migration from ILM has impacted groundwater quality conditions of the site.

In December 2004, the Ground Water Corrective Measure Study report was submitted to DTSC on behalf of Lockheed Martin Corporation. The report recommends a containment and control approach by use of Bioaugmentation (TRC, December 2004). The objective of this remedial approach is to prevent further migration of COCs to downgradient areas. DTSC has concluded that the proposed remedy is not acceptable because it does not address the off-site plume that is originated from ILM (DTSC, March 28, 2005).

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3.0 INTERIM REMEDIAL MEASURES

3.1 SOIL REMEDIAL MEASURES

BRC has implemented several remedial measures to remove the potential sources of COCs from the vadose zone. The implemented or ongoing measures are as follows:

- Removal of surface and subsurface features that may have contributed to the release of COCs into the subsurface environment.
- Soil vapor extraction (SVE) from the vadose zone.
- Installation of soil vapor barriers beneath the new buildings erected during the recent site development.

The above measures, particularly the operation of the SVE system have been effective in eliminating the sources of COCs and reducing the potential impact on future receptors including the underlying groundwater. A summary of SVE operation and effectiveness for the former Building 1/36 and Building 2 areas is presented below.

Interim SVE activities were conducted at the former Building 1/36 and former Building 2 areas from 2001 through 2004. The SVE treatment system extracted vapors from numerous single-completion and dual-completion wells installed in these areas. The extracted VOC-containing vapors were treated using a series of granular-activated carbon (GAC) vessels. At the former Building 2 area, SVE occurred from November 2001 to November 2002. Vapor extraction at the former Building 1/36 area was initiated with pilot testing in the first quarter of 2001 and continued with intermittent full-scale operation until the end of the third quarter of 2004. The SVE system was shut down on September 30, 2004 to allow for site reconstruction activities.

At the former Building 2 area, the compound showing the highest concentration in the SVE system influent was TCE. Additional compounds detected to a lesser extent included 1,1-DCE, chloroform, toluene, and PCE. During SVE treatment system operation from November 2001 to November 2002, an estimated 2,950 pounds of VOC mass was recovered (Haley & Aldrich, April 24, 2003).

At the former Building 1/36 area, TCE, TCA, 1,1-DCE, toluene, MEK, acetone, and xylenes were detected at elevated concentrations in the SVE system influent. From July 2001 through October 2004, the SVE system at the former Building 1/36 area recovered an estimated 30,215 pounds of VOC mass (Haley & Aldrich, October 25, 2004).

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Based on the above considerations, the vadose zone soil beneath the site is not expected to be a source of contamination for the underlying groundwater and therefore, is not included as the impacted media in this feasibility evaluation.

3.2 GROUNDWATER REMEDIAL MEASURES

Subsequent to the feasibility evaluation conducted in 2001, Arcadis selected an In-Situ Reactive Zone (IRZ) technology to enhance biodegradation of chlorinated VOCs in the B-Sand and C-Sand at the former Building 1/36 and Building 2 areas. Installed prior to erecting the new structures at the site, the system includes 166 wells in the former Building 1/36 area, 138 wells in the former Building 2 area, and the associated piping and equipment to convey amendments into the B-Sand and C-Sand.

Amendment points were installed to provide a mechanism for delivering carbohydrate solutions to target the impacted areas (Arcadis, August 13, 2004). The points were installed between 75 and 125 feet bgs and constructed with 10, 15, 20, or 25 feet of screen. The points were connected via lateral pipes to access vaults located along the perimeter of the buildings. The system layout is shown in Figure 22. The components of the amendment delivery system include temporary tanks, tanker trucks, injection system manifold, transfer hoses, and amendment point wellheads. The injection pressure can be controlled and monitored in the field based on characteristics of each individual point (Arcadis, September 14, 2004).

Upon completion of the system, Arcadis injected food grade carbohydrate (molasses) into the points through the manifold and delivery system. The design flow rate was 1,200 gallons per point. Within the first day of injection, molasses seeped into the floor of the buildings indicating that some of the injected molasses have not been delivered to the target zones in the Building 2 area. Also, injection into certain points appeared to reduce with time. Injection operations ceased and Arcadis conducted a number of tests to diagnose the issues and difficulties encountered. At Building 2, Arcadis conducted an alternate donor injection test to evaluate the viability of other amendment materials and to optimize injection criteria. Arcadis also performed pre-injection tests in certain wells at Lot 8 (Arcadis, January 7, 2005). Significant findings of the work performed by Arcadis are as follows:

- The seeps encountered in the buildings could have resulted from malfunctioning of the points, defects in the conveyance system, and/or flow through more permeable zones of the formation.
- Injection pressures have ranged from less than 5 psi to greater than 20 psi.
- Flow measurements indicate a range of less than 1 gpm to greater than 10 gpm.
- Out-of-range injection pressures may have contributed to the seeps

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- The radius of influence of injection is reportedly 3 feet in 15 days.
- The effectiveness of molasses injection has not been assessed by Arcadis.

Based on the above observations and site-specific experience, Arcadis proposed to change the amendment material from molasses to lactate, modify the injection procedures, increase injection volume, decrease concentration of amendment, and develop contingency plans for any future operations.

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4.0 SCREENING AND EVALUATION OF REMEDIAL TECHNOLOGIES

Prior to screening and evaluation of remedial technologies and process options, the conditions under which the previous feasibility evaluation was conducted and the rationale for the subject feasibility evaluation are discussed. Also, in this section source areas are defined, and remediation strategy is presented.

4.1 CONDITIONS UNDER PREVIOUS FEASIBILITY EVALUATION

In 2001, BRC completed a feasibility evaluation considering the site-specific conditions and circumstances at that time (Haley & Aldrich/England Geosystem, July 18, 2001). That feasibility evaluation for the source areas concluded that in situ bioremediation was the most appropriate remediation option. Justifications for proceeding with the implementation of the selected remedy were as follows:

- Source area (greater than 5,000 µg/ℓ TCE) remediation was a requirement by the LARWQCB.
- Mass reduction in source areas would reduce potential long-term treatment cost if BRC were to pay its share of remediation cost toward the regional remedy contemplated by the Del Amo/Montrose project.
- Remediation of other areas with lower TCE concentrations was considered technically achievable through monitored natural attenuation but economically impractical by other active technologies.
- There was adequate time to install the required infrastructure prior to erecting the buildings at the site.
- The Del Amo/Montrose project was relatively inactive allowing sufficient time for the selected in-situ bioremediation to be effective.
- Pump-and-treat and hydraulic control were not considered because there was not any short term impact of extraction/injection from the regional remedy planned for the Del Amo/Montrose project.
- Moving forward with the implementation of in-situ bioremediation reduced the chance of becoming a potentially-responsible party in the Del Amo/Montrose Superfund project.
- Based on previous successful experience and unique approach provided to BRC, the selected contractor utilized molasses as an amendment solution.

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4.2 RATIONALE FOR THE SUBJECT FEASIBILITY EVALUATION

During the planning stages of implementing the in-situ bioremediation and its subsequent operation certain unanticipated changes occurred which led to the initiation of this feasibility evaluation. These changes are outlined, as follows:

- Because of significant delays in granting the required permit, the source remediation was not performed prior to erecting the buildings but the amendment injection infrastructure was installed beneath the buildings.
- Application of molasses as the primary amendment material was not geochemically compatible with the site conditions and resulted in seeps around certain injection wells inside the building raising concerns with the current owners and tenants.
- Injection appeared to take longer than expected with an increase in the number of injections and time needed to accomplish the remediation objective.
- The U.S. EPA appears to be more active in pursuing the regional remedy, and if implemented in phases or full scale, it is expected to impact the site conditions.
- Construction of the remediation infrastructure in the former Building 1/36 area is not completed and thus, system modification is still possible.

4.3 SOURCE AREAS

As mentioned in Section 3.0, potentially-impacted soils beneath the site have either been remediated or are currently being mitigated. Therefore, soils beneath the site are not expected to be sources of contamination to the aboveground structures or underlying aquifers. Consequently, this feasibility evaluation does not address any vadose zone soils.

The definition of the source area depends on the hydrogeologic unit of interest. The source area in the B-Sand is defined as the area containing greater than 5,000 $\mu\text{g}/\ell$ of TCE. As shown in Figure 14, the greater than 5,000 $\mu\text{g}/\ell$ TCE area also encompasses the majority of elevated concentrations of 1,1-DCE. Therefore, it is likely that addressing the TCE source area would also address 1,1-DCE-impacted zone. Utilizing the known properties of the B-Sand, the mass of TCE and 1,1-DCE within the source area is approximately 990 lb. As shown in Table 3, this amounts to about one half of the total mass of TCE and 1,1-DCE in the B-Sand. Therefore, addressing the area with greater than 5,000 $\mu\text{g}/\ell$ of TCE would have a significant long-term impact on mitigation of the subsurface environment.

The concentrations of COCs in the C-Sand are significantly lower than those in the B-Sand. The source area in the C-Sand is defined as the area containing greater than 1,000 $\mu\text{g}/\ell$ of TCE. As shown in Figure 17, this area coincides with the area containing the highest concentrations of

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1,1-DCE. In addition, this area contains 81 percent of the total TCE and 1,1-DCE present in the C-Sand.

Currently, the extent of VOCs in the Gage Aquifer beneath the site is not known. Recent investigations conducted at the Del Amo/Montrose sites indicate presence of TCE in the Gage Aquifer near the southern boundary of the site. Based on this TCE detection, the U.S. EPA has directed the LARWQCB to require the facilities in the area to investigate the extent of VOCs in the Gage Aquifer. In response, BRC has installed two Gage Aquifer wells along the eastern site boundary. Preliminary data indicate that TCE is present in the Gage Aquifer at the downgradient boundary of the site. As the extent and source of TCE beneath the site are not known, it is assumed for the purpose of this feasibility evaluation that the Gage Aquifer beneath the source area contains TCE.

4.4 REMEDIATION STRATEGY

The overall strategy in this feasibility evaluation is developing alternatives that would reduce the concentrations of COCs in source areas. Reduction of concentrations in these areas would have the following consequences:

- Minimizing the lateral migration of COCs resulting in concentration reduction outside of the source areas which in turn would minimize off-site migration.
- Reducing the potential impact of COCs on vertical migration from the B-Sand and C-Sand toward the Gage Aquifer.
- Decreasing the possibility of impact of any extraction/injection that may be imposed by the Del Amo/ Montrose remedy.

The strategy for developing the remedial alternatives considers site-specific assumptions, constraints, and regulatory conditions, as follows:

- The infrastructure for applying amendments to the groundwater for the purpose of in-situ remediation will be completed in the Building 1/36 and Building 2 areas.
- The areas inside the new buildings are not accessible for any modification to the existing system or monitoring.
- The existing amendment wells and the associated conveyance system are suitable for injecting amendment materials into the underlying groundwater.
- The U.S. EPA-directed remedy for the Del Amo/Montrose project is expected to have an effect on site conditions within the next 3 years.

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4.5 REMEDIATION TECHNOLOGY SCREENING CRITERIA

To screen and evaluate applicable remedial technologies and process options, effectiveness, implementability, and cost were used as the principal criteria. In addition, other factors such as acceptability to regulatory agencies and stakeholders were also considered.

4.5.1 Effectiveness

Effectiveness of a remedial technology is evaluated relative to other remedial options for achieving specific remedial objectives. Another factor in the evaluation of effectiveness is the reliability of a technology to remove, destroy, or treat the COCs. A remedial technology will be considered effective if it achieves remedial objectives within a reasonable time frame.

4.5.2 Implementability

Implementability is evaluated in terms of technical and administrative feasibility of a particular remedial option. Permitting, availability of equipment, access, and achieving target remedial objectives are among the factors that affect implementability.

4.5.3 Cost

An order of magnitude cost is sufficient during the screening process of remedial technologies because it provides a basis for comparing various technologies considered. A more refined cost analysis shall be performed during the selection of remedial alternatives and will be submitted to BRC as a separate document.

4.6 POTENTIALLY-APPLICABLE REMEDIAL TECHNOLOGIES

Considering the site conditions and experience in similar projects, the potentially-applicable remedial technologies were considered and screened. Potentially-applicable remedial technologies screened are as follows:

- No action
- Monitored natural attenuation
- Hydrogen sparging
- Enhanced bioremediation
- Permeable reactive barrier
- In-situ oxidation
- Dual-phase extraction
- Hydraulic containment

The technologies that were rejected in the previous feasibility evaluation were eliminated at the outset unless current conditions dictate otherwise. Also, the technologies that were not supported by proven field-applied record were not retained for further consideration.

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Considering the site-specific conditions, the retained remedial technologies are grouped under two categories, one for the B-Sand and C-Sand and the other for the Gage Aquifer.

4.6.1 Remedial Technologies for the B-Sand and C-Sand

Potentially-applicable remedial technologies for the B-Sand and C-Sand are as follows:

- Monitored natural attenuation
- Enhanced in-situ bioremediation (EISB)
- EISB with Bioaugmentation
- In-situ chemical oxidation
- Hydraulic Containment

Monitored Natural Attenuation

Monitored natural attenuation (MNA) includes the use of existing groundwater wells to monitor the changes in concentrations of COCs as a result of attenuation parameters including dispersion, adsorption, biodegradation, and volatilization. The advantage of MNA is the least effort and cost. The disadvantages include least chance of acceptance and most likely to require future actions because of lateral and vertical expansion of VOCs

Effectiveness: Natural attenuation would be effective in containing the COCs in certain areas of the site.

Implementability: Technically, natural attenuation is not intrusive and can easily be implemented. Administratively, it may not be acceptable to the agencies and stakeholders.

Cost: The cost is expected to be low and will depend on the extent of the applicability, demonstration of its effectiveness, and monitoring requirements.

Based on these considerations, for the source areas, MNA is not retained for further evaluation.

Enhanced In-Situ Bioremediation

Enhanced biodegradation is considered a viable source-area plume remediation technology. Groundwater geochemistry provides strong evidence of active VOC biodegradation in the Building 1/36 area. This conclusion is based on the natural attenuation monitoring data discussed earlier and appears to be a function of the presence of the organic contaminants contributing to a reducing environment which facilitates the chlorinated solvent biodegradation. Other processes such as the aerobic cometabolic biodegradation of VOCs exist at the southern site boundary based on the relatively high oxygen concentrations in site groundwater and the

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presence of chlorobenzene (a possible cometabolite) near the southern boundary and at the adjacent Montrose site.

Enhanced biodegradation could be effective if amendments are used to overcome the observed lack of donor electrons in the Building 2 area and are used to augment the ongoing processes at the Building 1/36 area. This process would create the reducing environment and provide nutrients necessary for source plume remediation. Enhanced biodegradation can be applied by direct amendment injection into the source area water-bearing zone.

The two primary amendment alternatives that have been considered for the site include Hydrogen Releasing Compound (HRC) and carbohydrates. HRC is designed to consume available oxygen and create reducing conditions in the aquifer with a slow release of electrons via lactic acid degradation. HRC enhances the reductive dechlorination processes in groundwater and has diffusion properties which eliminate the need for direct mixing/intimate contact with all aquifer waters. Carbohydrate injection of either molasses, glucose, or sodium lactate into the aquifer stimulates anaerobic degradation processes in aquifers by consuming available oxygen and releasing hydrogen through fermentation. The hydrogen acts as an electron donor which enhances the reductive dechlorination of contaminants. Methane is produced as a byproduct of the fermentation process. Degradation rates for carbohydrates are relatively fast, requiring frequent additions and larger volume applications to create necessary mixing to keep degradation processes.

It is assumed that the existing infrastructure is adequate for the application of these amendments. Based on site-specific experience and case studies, sodium lactate has been retained as the amendment material.

The advantages include acceptance by agencies, low capital cost, and effectiveness in reducing concentrations in the dissolved and adsorbed phases. The disadvantages include possible operational difficulties, possible interference with current owners and tenants operations, uncertain amendment half-life, uncertain effectiveness in biologically active zone (BAZ), potential for incomplete transformation particularly at the former Building 2 area, and possibly longer than 5-year duration. The method is applicable for the site since it is a passive process and does not negatively influence hydraulic gradients.

- Effectiveness:** In-situ bioremediation is effective except in isolated zones where the amendments cannot come in contact with the formation material or the pore space.
- Implementability:** Technically or administratively, there is no problem associated with the implementation of this technology. .
- Cost:** The cost is considered high particularly if multiple injection of amendment is applied.

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This technology is retained for further consideration.

EISB with Bioaugmentation

This technology involves introduction of *D. Ethenogenes*-containing culture to the groundwater to overcome the biological limitations or accelerate complete dechlorination. The advantages include demonstration of effectiveness for TCE-impacted groundwater, effective in carrying the transformations to final products (carbon dioxide and water), and applicability to the existing infrastructure. The disadvantages include unknown BAZ, variable BAZ depending on media heterogeneity, and lack of many documented large-scale cases.

Effectiveness: This technology is effective except in zones where contact between the organisms and the impacted media is limited.

Implementability: Technically it is implementable. Administratively permitting could be an issue of concern.

Cost: Cost is considered high if multiple injections are applied.

This technology is retained for further consideration.

In-Situ Chemical Oxidation

In-situ chemical oxidation involves reduction of chlorinated VOCs using oxidants. Potassium permanganate (KMnO_4) and Fenton's Reagents are the most common oxidants. The advantages of in-situ chemical oxidation are effectiveness within a short time after application and suitability of existing infrastructure. It is effective under a wide range of pH conditions (Schwartz and Zhang, 2000, Huang et al., April 23, 2001). The disadvantages include possible reduction in hydraulic conductivity, potential increase in mobility of other organic and inorganic compounds, and lengthy permitting process. Another disadvantage is possible reaction with residual amendments (molasses) within the conveyance piping that could foul the injection points with precipitate generated during the reaction. Also, if there are significant amendments remaining in the subsurface from previous injection events, more oxidant would be required to overcome the demand of the residual amendments.

Effectiveness: Chemical oxidation is an effective technology to transform chlorinated VOCs to nonhazardous compounds. The reactions are rapid. Effectiveness depends on mixing capability.

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Implementability: Chemical oxidation is considered technically feasible but administratively time consuming because of permitting requirements.

Cost: Potentially cost-effective, particularly if the infrastructure exists.

This technology is retained for further consideration.

Hydrogen Sparging

This technology involves injection of hydrogen gas into the impacted media to microbially reduce the chlorinated VOCs. Under a controlled environment, this technology has been effective and it has been implemented in small-scale projects. Prior to implementation it requires a pilot test. The advantages include minimum cost among all donors, non-toxic, and leaves no residual in groundwater. The main disadvantage is possible combustion if not handled properly. Also this technology is not demonstrated in large-scale projects.

Effectiveness: Hydrogen sparging is theoretically an effective option to dechlorinate VOCs but field-applied cases of success are not available.

Implementability: Hydrogen sparging may not be technically and administratively feasible.

Cost: Considered potentially cost-effective because hydrogen is an inexpensive gas.

This technology is not retained for further consideration.

Hydraulic Control

This technology intercepts the plume downgradient of the source area using groundwater extraction and/or injection systems. The extracted water is to be treated prior to discharge into the storm drain, sanitary sewer, or injection into the aquifer. The advantages include proven record for plume containment, removal of VOC mass, reduction in concentrations, enhancing groundwater recirculation, decreasing hydraulic head potential which reduces vertically downward gradient toward the Gage Aquifer. If combined with injection, this technology would have the advantage of recirculating the extracted water and enhancing the effectiveness of amendments. The disadvantages include long operation time and access constraints and possible interference with the site owners and tenants operations.

Effectiveness: Hydraulic control is considered a potentially effective way to inhibit contaminant migration and help achieve the remedial objectives, although treatment of the extracted ground water would be required.

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Implementability: Hydraulic control is considered technically and administratively feasible.

Cost: Hydraulic control is considered potentially cost-effective, even with the cost of treatment and a suitable discharge option.

This technology is retained for further consideration.

4.6.2 Remedial Technologies for the Gage Aquifer

Potentially-applicable remedial technologies for the Gage Aquifer are as follows:

- Monitored natural attenuation
- Financial contribution to regional remedy
- In-situ bioremediation
- Hydraulic containment

G1. Monitored Natural Attenuation

The existing wells installed by BRC and the monitoring network established for the Montrose/Del Amo project can be utilized to monitor changes in concentrations of COCs. These changes may result from one or combination of the following sources:

- COCs that may originate from the Former C-6 Facility
- COCs that may have originated from ILM located to the west of the Former C-6 Facility
- COCs that may have evolved from the East Normandie Sites
- COCs that may have entered into the southern portion of the Former C-6 Facility from the Montrose site.

Depending on the extent of COCs in the Gage Aquifer beneath the site relative to the off-site areas, MNA may be a viable remedial technology.

The advantage of MNA is its least effort and cost. The disadvantage of implementing MNA is the likelihood that the site becomes a part of the regional remedy and Superfund process. In that context, MNA may not be an acceptable technology to the stakeholders.

G2. Financial Contribution to the Regional Remedy

This option assumes that BRC has contributed to the degradation of the Gage Aquifer, but does not take an active role in remediation. In this case, BRC may choose to pay its share of contribution to the regional remedy. The allocation of responsibility can be formulated based on

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previous cases in operable units consisting of multiple potentially responsible parties (PRPs). Individual plume analysis is among the accepted methodologies for cost allocation particularly for groundwater pump-and-treat systems. The total cost of regional remedy is related in some proportion to the volume of water pumped and mass of contaminants treated. A proportion of 70 percent for volume and 30 percent for mass has been adopted in certain operable units by U.S. EPA. Considering the contribution of volume and mass from the site relative to the total regional remedy, the cost of remediation of any BRC-related plume can be computed.

An advantage of this option is that it does not interfere with the current owners and tenants operations. The main disadvantage of this option is least control by BRC over the operation, cost, and schedule of the regional remedy. Other disadvantages are that BRC may be named as a PRP to the Superfund process and that possible delays in implementation of the regional remedy will tend to escalate the cost because the BRC-related plume will be larger with larger contribution to the total remedy. This option is retained for further consideration.

G3. Enhanced In-Situ Bioremediation

The mechanisms and processes for application of this technology are the same as described earlier for the B-Sand and C-Sand. However, because of anticipated low concentrations of COCs in the Gage Aquifer, EISB may not be an effective technology. In addition, the cost of applying EISB is expected to be much higher for deeper wells. Therefore, this technology is not currently retained for further consideration for the Gage Aquifer but may be applicable after characterization of the Gage aquifer contamination and identification of its source are completed.

G4. Hydraulic Containment

Hydraulic containment of the plume in the Gage Aquifer applies to the downgradient site boundary along the southeast perimeter of the site. This can be accomplished through pumping from wells perforated in the Gage Aquifer. The extracted groundwater can be treated using GAC or air stripping. Hydraulic control would prevent off-site migration of COCs, will not impact any off-site remedy because the flow rates will be much smaller than those contemplated by the regional remedy, and help keep the site isolated from the Superfund process. One of the disadvantages of pumping from the Gage Aquifer is that it may expedite vertical migration of COCs from the C-Sand toward the Gage Aquifer if the hydraulic head in the C-Sand is not reduced accordingly. This technology is retained for further consideration.

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5.0 DEVELOPMENT OF REMEDIAL ALTERNATIVES

One or a combination of remedial technologies presented in Section 4.0 may be appropriate as the remedial alternative(s) for the B-Sand, the C-Sand, and the Gage Aquifer. As the schedule for implementation of the Montrose/Del Amo regional remedy is uncertain and water quality of the Gage Aquifer beneath the site is unknown, development of remedial alternatives should be based on certain assumptions and constructing likely scenarios, as described below.

U.S. EPA is currently engaged in further investigation of the areas that may impact the full-scale remedy. According to the ROD (March 1999), the full-scale regional remedy would involve groundwater extraction rates exceeding 700 gpm. The drawdown associated with these rates is expected to affect the flow regime beneath the Former C-6 Facility. In addition, large-scale pilot tests are being planned by the Montrose/Del Amo PRPs to evaluate the effectiveness of extraction/injection on the existing plumes. Pumping rates of 200 gpm are expected during pilot tests. Furthermore, U.S. EPA is conducting groundwater and contaminant transport modeling to understand the flow regime and migration behavior of contaminants and to help design the full-scale remedy. Subsequent to completing the detailed design, development of a bid package, and contractor selection, the construction of the system is expected to begin. The entire process is anticipated to take approximately 5 years in which case the regional remedy will not have any effect on the site groundwater conditions. However, based on discussions with U.S. EPA, the large-scale pilot tests are planned to be part of a phased approach to implementation of the full-scale remedy. Therefore, long-term operation of the pilot tests is likely. Based on these considerations, it is possible that in the next two years, extraction/injection from large-scale pilot tests would have an effect on the flow regime beneath the site.

With respect to the quality of water in the Gage Aquifer, two scenarios are contemplated, as follows:

- The first scenario assumes that peak concentrations of COCs in the Gage Aquifer are beneath the site and that the COCs have originated from the Former C-6 Facility.
- The second scenario assumes that peak concentrations of COCs are off site and that the Former C-6 Facility will not act as a long-term source of contamination to the Gage Aquifer downgradient of the site.

Based on these considerations and assumptions, two alternatives are formulated. The conditions and components of the two alternatives are presented below.

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5.1 ALTERNATIVE 1

Alternative 1 assumes that although full-scale regional remedy may not begin until 2010, the large-scale pilot tests would have an impact on the flow conditions beneath the site. Table 4 presents an assumed schedule for the implementation of the Montrose/Del Amo remedy. It is also assumed that peak concentrations of the COCs in the Gage Aquifer are on site. Considering these assumptions and the remedial technologies discussed in Section 4.0, possible components of Alternative 1 for the B and C-Sands and the Gage Aquifer are as follows:

B-Sand and C-Sand

EISB
Performance monitoring
Bioaugmentation
Chemical oxidation to replace or backup EISB
Hydraulic containment

Gage Aquifer

Hydraulic containment
Groundwater monitoring

Alternative 1 may include one or more of the these components. The schedule for one possible sequence of components for Alternative 1 is presented in Table 4. The rationale and effectiveness for each component of Alternative 1 are presented below. The cost shall be provided to BRC in a separate document.

5.1.1 Existing EISB System Operation

Previous observations during amendment injection at the former Building 2 area are being analyzed to understand the system behavior and to streamline amendment injection for not only the former Building 2 area but also for the former Building 1/36 area. Based on evaluation of EISB at the site and past practices at other facilities, the following factors and modifications need to be considered:

- Rehabilitate the amendment points and lines to accommodate future injections.
- Based on previous observations and testing, estimate injection pressures and flow rates to optimize the injection process
- Consider utilization of sodium lactate as the amendment solution.
- Identify the points that may lead to occurrence of seeps and leaks.
- Follow injection and flow guidelines to prevent seeps and leaks.

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- Conduct performance evaluation after each injection.

The schedule presented in Table 4 assumes that EISB can begin in mid 2005 at the former Building 2 area and proceed to the former Building 1/36 area once the infrastructure is complete. Detailed design and construction associated with any hydraulic control measures need to be coordinated with Lot 8 construction activities.

5.1.2 Performance Evaluation

The data collected from previous injections and those obtained thereafter shall be analyzed and compared to the baseline data to assess the impact of EISB on water quality of the B-Sand and C-Sand. A performance monitoring plan shall document observations and measurements during amendment injection including injection pressure, volume, and rate of injected volume, hydraulic head changes, and water quality data. The performance evaluation results shall be utilized to make appropriate modifications in future injections, if necessary.

5.1.3 EISB with Bioaugmentation

Bioaugmentation is selected to complement EISB if performance evaluations demonstrate that either the rates of degradation of TCE and 1,1-DCE are slow or that transformation of chlorinated VOCs is incomplete. Some sites do not appear to have the appropriate microbial population to achieve complete transformation of TCE to ethane. Under these conditions, addition of Dehalococcoides-containing microbial culture to groundwater to facilitate complete dechlorination to ethane may be appropriate.

The literature data indicates that bioaugmentation can be effective in transforming TCE to ethene within a reasonable time frame. At the Dover Air Force Base, bioaugmentation was performed by injecting *D. ethenogenes*-containing culture. Upon implementation and as part of performance monitoring, real-time polymerase chain reaction (PCR) should be performed to monitor the survival and proliferation of *D. ethenogenes*.

5.1.4 Chemical Oxidation as Replacement or Backup for EISB

If performance evaluation demonstrates that EISB without or with bioaugmentation is not effective, chemical oxidation can be used to address the source areas. Considering the anticipated duration of EISB, BRC may choose chemical oxidation without further reliance on EISB. Potassium permanganate is selected as the oxidant of choice. The main advantage of chemical oxidation is that the infrastructure for application of oxidants is in place. Another advantage is that the reaction between the oxidant and the chlorinated VOCs is rapid and therefore, there is less likelihood of lateral and vertical migration of VOCs with time. The principal disadvantage of chemical oxidation is reduction in hydraulic conductivity because of production of manganese oxides and carbon dioxide which may clog the pore space. Reduction in hydraulic conductivity

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is more in the presence of dense non-aqueous phase liquids (DNAPL). As there is no documentation of presence of DNAPL at the site, the effect on hydraulic conductivity reduction may not be significant. However, because of possible need of multiple applications at each amendment point, production of manganese oxides and carbon dioxide may reduce hydraulic conductivity. Specifically, if hydraulic conductivity is reduced after the first or second injection, effectiveness of further application of potassium permanganate will decrease because the same amendment points need to be utilized. If the schedule presented in Table 4 is followed, before full-scale application, injection of potassium permanganate to a small area as a pilot test shall provide valuable information. However, prior to any test, it is appropriate to evaluate the oxidant demand to estimate the amendment requirements.

5.1.5 Hydraulic Containment in the B-Sand and C-Sand

Hydraulic containment of the B-Sand and C-Sand plumes can be accomplished by a series of extraction wells located downgradient of the source areas. Simulations were performed to estimate the zone of capture associated with a given set of wells and specified configuration. The code RESSQ (Javandel et al., 1984) was used to estimate the zone of capture associated with the simulated ground water extraction in the B-Sand and C-Sand. RESSQ calculates the streamline pattern created by the regional hydraulic gradient and groundwater extraction. The analytical model assumes that the regional flow field is uniform and the aquifer is homogeneous, isotropic, confined, and of uniform thickness. Separate model simulations were performed for the B-Sand and C-Sand. For each simulation, it was assumed that no leakage occurred from the less-permeable overlying and underlying formations.

B-Sand Capture Zone Analysis

The model input parameters for the B-Sand simulation are summarized in Table 5. The resulting streamline pattern is presented in Figure 23. A hydraulic conductivity of 20 ft/day was used for the model simulation (CH2M Hill, 2004). Previous investigations have shown the saturated thickness of the B-Sand to range between 25 and 30 feet below ground surface (Haley & Aldrich, 2002). An average saturated thickness of 27.5 feet was used as input to the model. Input values for the regional groundwater flow direction and gradient were based on reported values during the 2004 groundwater monitoring (Haley & Aldrich, 2004). Specifically, a southerly regional flow direction with a hydraulic gradient of 0.001 was used in the model. Assuming a porosity of 0.3, the average groundwater flow velocity was calculated as 24.3 feet per year.

A total of eight proposed groundwater extraction wells were used in the model simulation. The locations of these wells are shown in Figure 23. Figure 23 also shows a generalization of two separate "source areas" within the B-Sand which contain TCE at concentrations exceeding 5,000 µg/l. One source area is in the former Building 2 area while the second is predominantly within Lot 8. Four of the proposed wells are located in Lot 8 and four are located in the former Building 2 area. The simulated extraction rate for each of the eight wells was 3 gpm. This

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extraction rate is based on the sustainable B-Sand injection rates that have been observed during recent bio-amendment pilot tests.

The streamline patterns, presented in Figure 23, show the zone of capture after one year and five years of extraction. The capture zone indicates that all areas containing TCE above 5,000 $\mu\text{g}/\ell$ will be contained. Assuming an average concentration of 5,000 $\mu\text{g}/\ell$ in the extracted groundwater, the rate of TCE mass removal for a total extraction rate of 24 gpm from the B-Sand would be 1.4 pounds per day.

C-Sand Capture Zone Analysis

The model input parameters for the C-Sand simulation are summarized in Table 5 and the resulting streamline pattern is presented in Figure 24. A hydraulic conductivity of 145 ft/day was used for the model simulation (CH2M Hill, 2004). Previous investigations have shown the saturated thickness of the C-Sand to range between 13 and 21 feet below ground surface (Haley & Aldrich, 2002). An average saturated thickness of 17 feet was used as input to the model. Input values for the regional groundwater flow direction and gradient were based on water levels measured during March 2004. Specifically, a southeasterly regional flow direction with a hydraulic gradient of 0.0010 was used in the model. Assuming a porosity of 0.3, the groundwater flow seepage velocity was calculated as 176 feet per year.

A total of six proposed C-Sand groundwater extraction wells were used in the model simulation. The locations of these wells are shown in Figure 24. Figure 24 also shows a generalization of two separate "source areas" within the C-Sand which contain TCE at concentrations exceeding 1,000 $\mu\text{g}/\ell$. One source area is in the former Building 2 area while the second is within Lot 8. Three of the proposed wells are located in Lot 8 and three are located in the former Building 2 area. The simulated extraction rate for each of the six wells was 10 gallons per minute (gpm). This extraction rate is assumed to be sustainable based on the thickness and hydraulic conductivity within the C-Sand.

The streamline patterns, presented in Figure 24, show the zone of capture after six months, one year, and two years of extraction. The capture zone indicates that all areas containing TCE above 1,000 $\mu\text{g}/\ell$ will be contained. Assuming an average concentration of 1,000 $\mu\text{g}/\ell$ in the extracted groundwater, the rate of TCE mass removal for a total extraction rate of 60 gpm from the B-Sand would be 0.7 pounds per day.

Groundwater Treatment Technologies

The extracted groundwater shall be subject to treatment prior to surface discharge, reinjection back into the aquifer, or reuse. The most common treatment technologies for VOC-impacted groundwater are GAC and air stripping.

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Discharge Options

Options for handling the treated groundwater include discharge into the storm sewer, sanitary sewer, or reinjection into the aquifer. Among the three options, reinjection of treated water into the aquifer is most beneficial because it enhances recirculation of water and amendments within the aquifer which in turn increases the contact between the amendment and the media of concern. Discharge into the storm drain will be subject to an NPDES permit. .

5.1.6 Hydraulic Containment in the Gage Aquifer

Under Alternative 1, it is assumed that TCE concentrations in the Gage Aquifer beneath the site are higher than in off-site areas. Under this assumption, hydraulic containment will capture the COCs in the Gage Aquifer and will prevent off-site migration to downgradient areas. As the nature and extent of distribution of COCs in the Gage Aquifer are not known, capture zone analysis is not performed. However, as hydraulic properties of the Gage Aquifer are anticipated to be similar to the B-Sand (CH2M Hill, October 2004), three to five wells may be needed to contain an on-site plume. It was assumed that 3 wells extracting 5 gpm each would be sufficient to capture any onsite plume. This component of Alternative 1 is valid as long as the regional remedy or large-scale extraction/injection during the planned pilot tests do not impact the site conditions. Otherwise, extraction of several hundred gallons per minute from off-site wells for the pilot tests or as a component of regional remedy is expected to significantly affect the hydraulic potentials in the Gage Aquifer, i.e. the drawdown associated with the regional remedy is expected to be much more than the drawdown caused by pumping from the Gage Aquifer wells. Under this scenario, much higher flow rates will be needed to capture any COCs originating from the Former C-6 Facility and to compensate any drawdown associated with off-site extraction/injection. An alternate approach is to compensate the Montrose/Del Amo PRPs for BRC's share of remedy.

5.2 ALTERNATIVE 2

Alternative 2 assumes that all conditions of Alternative 1 prevail except that peak concentrations of TCE in the Gage Aquifer are not detected beneath the site. Under these conditions, it would be reasonable to assess BRC's contribution to the regional remedy and allocate cost appropriately. As mentioned earlier, the contribution from the Former C-6 facility can be estimated by individual plume analysis or other means, as necessary. The individual plume analysis would be based on the following information, assumptions, and procedures:

Known extent and concentrations of COCs originated from the Former C-6 Facility to calculate the volume of water and mass of COCs

Known zone of off-site contamination to compute the total volume of water and mass of contaminants required to be treated by the regional remedy

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Assessment of proportions of cost related to the volume of water extracted and treated and the mass of contaminants recovered.

Calculating the contribution of the plume associated with the Former C-6 facility relative to the total plume

Upon availability of the Gage Aquifer water quality data collected by BRC, the individual plume analysis calculations can be made to assess approximate cost of allocated share for any COCs that may have originated from the Former C-6 Facility.

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Tables

Table 1

Groundwater Monitoring Well Completion Information

Boeing Realty Corporation, Former C-6 Facility
Los Angeles, California

Well I.D.	Water Bearing Unit	Easting ¹	Northing ¹	Top of Casing Elevation (AMSL) ^{2,3,4}	Boring Total Depth (feet)	Screen Depth Interval (feet)	Depth to Top of Filter Pack (feet)	Casing Diameter (inches)	Casing Type	Slot Size (inches)	Drilled Date
WCC-3S	B-Sand	6,470,384	1,770,027	51.12	92	69-89	64	4	Sched 40 PVC	0.010	10/26/1987
WCC-4S	B-Sand	6,470,516	1,769,863	49.62	92	70.5-90.5	65	4	Sched 40 PVC	0.010	10/27/1987
WCC-5S	B-Sand	6,470,738	1,769,786	48.79	91	61-91	64	4	Sched 40 PVC	0.010	11/24/1987
WCC-6S	B-Sand	6,470,354	1,769,741	51.30	91	60-90	54	4	Sched 40 PVC	0.010	9/22/1989
WCC-7S	B-Sand	6,470,504	1,769,656	50.20	91	60-90	54	4	Sched 40 PVC	0.010	6/8/1989
WCC-9S	B-Sand	6,470,702	1,769,415	57.40 ⁵	92	60-90	55	4	Sched 40 PVC	0.010	9/21/1989
WCC-12S	B-Sand	6,470,523	1,769,503	46.92	92	60-90	55	4	Sched 40 PVC	0.010	9/17/1990
DAC-P1	B-Sand	6,468,969	1,769,781	52.75	90	60-90	55	4	Sched 40 PVC	0.010	9/25/1989
TMW-4	B-Sand	6,470,265	1,769,113	48.79	84	58-78	56	2	Sched 40 PVC	0.010	6/30/1998
TMW-6	B-Sand	6,470,310	1,768,715	49.50	93	67-87	66	2	Sched 40 PVC	0.010	7/1/1998
TMW-7	B-Sand	6,470,334	1,769,489	52.52	91	65-85	63	2	Sched 40 PVC	0.010	6/29/1998
TMW-8	B-Sand	6,470,346	1,769,600	53.99	90	61-81	59	2	Sched 40 PVC	0.010	6/29/1998
TMW-10	B-Sand	6,470,740	1,768,957	47.48	85	60.5-80.5	58	2	Sched 40 PVC	0.010	1/28/1999
TMW-11	B-Sand	6,470,738	1,768,210	47.41	83	58-78	55	2	Sched 40 PVC	0.010	2/1/1999
TMW-14	B-Sand	6,469,567	1,768,206	58.91 ⁵	90	65-85	63	2	Sched 40 PVC	0.010	2/3/1999
TMW-15	B-Sand	6,469,572	1,768,955	55.23	92	62-87	60	2	Sched 40 PVC	0.010	2/4/1999
BL-03	B-Sand	6,468,979	1,768,753	56.48	79	59-79	56	2	Sched 40 PVC	0.010	2/8/1999
MW0005	B-Sand	6,470,243	1,796,060	49.57	87	65-85	63	4	Sched 40 PVC	0.010	8/8/2003
MWB012	B-Sand	6,470,065	1,768,993	52.43 ⁵	90.5	64.5-84.5	62	4	Sched 40 PVC	0.010	5/17/2004
MWB013	B-Sand	6,469,613	1,769,393	55.33 ⁵	86.5	65-85	62	4	Sched 40 PVC	0.010	5/17/2004
MWB014	B-Sand	6,470,281	1,768,401	51.69 ⁵	86.5	65-85	62	4	Sched 40 PVC	0.010	5/17/2004
MWB019	B-Sand	6,469,963	1,768,134	55.18 ⁵	90.5	65-85	62	4	Sched 40 PVC	0.010	5/17/2004
XMW-09	B-Sand	6,470,423	1,767,936	53.16 ⁵	-	66-81	-	4	-	-	5/9/1989
XMW-19	B-Sand	6,470,739	1,768,545	46.53	-	63-79	-	4	-	-	3/30/1990
CMW0001	C-Sand	6,470,711	1,768,180	54.37 ⁵	124	99-124	97	4	Sched 40 PVC	0.010	8/15/2003
CMW0002	C-Sand	6,470,556	1,767,936	52.81 ⁵	124	99-124	97	4	Sched 40 PVC	0.010	9/5/2003
CMW026	C-Sand	6,470,290	1,768,600	48.94	117	92-117	90	4	Sched 40 PVC	0.010	8/6/2003
MWC015	C-Sand	6,470,239	1,768,805	51.51 ⁵	128	100-125	126.5	4	Sched 40 PVC	0.010	5/17/2004
MWC016	C-Sand	6,469,997	1,768,713	52.61 ⁵	131	102.5-127.5	101	4	Sched 40 PVC	0.010	5/17/2004
MWC017	C-Sand	6,469,979	1,768,134	55.16 ⁵	128	100-125	99	4	Sched 40 PVC	0.010	5/17/2004

Table 1

Groundwater Monitoring Well Completion Information

Boeing Realty Corporation, Former C-6 Facility

Los Angeles, California

Well I.D.	Water Bearing Unit	Easting ¹	Northing ¹	Top of Casing Elevation (AMSL) ^{2,3,4}	Boring Total Depth (feet)	Screen Depth Interval (feet)	Depth to Top of Filter Pack (feet)	Casing Diameter (inches)	Casing Type	Slot Size (inches)	Drilled Date
MWC021	C-Sand	6,470,724	1,768,929	54.53 ⁵	126	97-122	95	4	Sched 40 PVC	0.010	5/17/2004
Wells to be Installed in 2005 ⁶											
MWB006	B-Sand	TBD	TBD	TBD	~85	~65-85	~83	4	Sched 40 PVC	0.010	TBD
MWB007	B-Sand	TBD	TBD	TBD	~85	~65-85	~83	4	Sched 40 PVC	0.010	TBD
MWB009	B-Sand	TBD	TBD	TBD	~85	~65-85	~83	4	Sched 40 PVC	0.010	TBD
MWC011	C-Sand	TBD	TBD	TBD	~120	~100-120	~98	4	Sched 40 PVC	0.010	TBD
MWB020	B-Sand	TBD	TBD	TBD	~85	~65-85	~83	4	Sched 40 PVC	0.010	TBD
MQC022	C-Sand	TBD	TBD	TBD	~120	~100-120	~98	4	Sched 40 PVC	0.010	TBD
MWB027	B-Sand	TBD	TBD	TBD	~85	~65-85	~83	4	Sched 40 PVC	0.010	TBD
MWB029	B-Sand	TBD	TBD	TBD	~85	~65-85	~83	4	Sched 40 PVC	0.010	TBD

¹ California State Plane NAD 83, Zone 5, Feet² AMSL = Above Mean Sea Level - Wells were surveyed March 19, 2002 & September 13, 2002 by Tait & Associates.³ Wells TMW-4 and TMW-6 were cut down during redevelopment activities. These wells were re-surveyed by Thienes Engineering, Inc. in October 2003.⁴ Wells installed in 2004 were surveyed by Tait & Associates in May 2004.⁵ Wells resurveyed by Tait & Associates in September 2004.⁶ Groundwater monitoring wells planned to be installed by end of 2005, data are proposed values.

- = not available

TBD = to be decided

Table 2

Historical Monitored Natural Attenuation ParametersBoeing Realty Corporation, Former C-6 Facility
Los Angeles, California

Well I.D.	Monitoring Date	Dissolved Oxygen (mg/L)	Oxidation Reduction Potential (mV)	pH	Conductivity (uS/cm)	Temperature (°C)
BL-03	03/26/02	7.77	115	7.58	3,300	23.4
	03/27/03	7.32	83	6.36	2,750	23.2
	03/23/04	3.66	121	7.1	2,970	23.1
	03/04/05	3.96	10	6.88	2,650	24.4
CMW001	10/09/03	2.59	-120	6.8	948	23.3
	03/23/04	0	-185	6.96	1,070	23.2
	09/24/04	0.3	-141	7.27	1,000	23.2
	12/21/04	3.58	-108	8.29	940	23.1
	01/05/05	0.52	-95.3		1,017	23.0
	03/03/05	0	-180	7.29	887	23.4
	03/18/05	0.17	-62.2		806	23.5
CMW002	10/08/03	2.17	51.4	6.91	788	23.0
	03/23/04	0	-29	7.28	980	22.8
	09/24/04	0.3	-49	7	600	23.5
	12/21/04	0.75	-56	6.78	888	23.1
	01/03/05	0.45	-6.6		875	22.5
	03/04/05	0	-82	6.83	88	23.1
	03/18/05	0.19	-56.7		699	22.6
CMW026	10/07/03	4.51	34	7.15	965	22.3
	03/24/04	2.24	-94	6.98	1,270	22.2
	05/21/04	0.3	26.4		1,016	21.6
	09/23/04	0.5	-126	6.19	1,420	23.1
	10/22/04	1.08	-86.7		123	22.7
	11/19/04	0.65	-202.7		384	24.0
	12/21/04	4.09	-114	7.56	1,580	22.6
	01/05/05	1.6	-13.8		72	22.3
	01/28/05	0.13	-108.7		459	22.6
	03/07/05	0	-149	6.42	1,610	22.6
	03/19/05	3.55	12.8		64	22.2
DAC-P1	03/27/02	5.77	82	7.16	2,000	23.4
	03/28/03	9.98	86	7.16	2,440	22.1
	09/24/03	5	66	6.91	22,000	23.1
	03/25/04	2.04	-72	6.88	179	23.3
	09/22/04	1.55	58	6.44	2,440	23.7
	09/24/04	3.2	84	6.8	1,900	23.1
	03/07/05	0.19	-60	6.85	2,450	23.4
MWB012	05/06/04	0.12	147	6.69	1,560	23.9
	07/16/04	2.9	49	6.36	1,430	23.7
	09/22/04	2.37	-121	8.08	1,790	23.1
	12/21/04	6.02	59	8.11	1,540	22.4
	03/03/05	5.68	80	6.87	1,970	22.5
MWB013	05/07/04	4.393	93	7.39	2,310	24.3
	07/15/04	2.25	86	4.29	46	27.3
	09/20/04	3.07	36	7.04	2,240	23.4
	12/20/04	6.55	89	8.32	2,590	23.0

Table 2

Historical Monitored Natural Attenuation Parameters

Boeing Realty Corporation, Former C-6 Facility
Los Angeles, California

Well I.D.	Monitoring Date	Dissolved Oxygen (mg/L)	Oxidation Reduction Potential (mV)	pH	Conductivity (uS/cm)	Temperature (°C)
MWB014	03/01/05	3.18	23	7.02	2,230	23.2
	05/07/04	1.86	83	7.12	951	23.1
	07/15/04	1.8	75	8.53	550	24.5
	09/22/04	0.95	37	6.58	942	23.3
	12/20/04	3.52	-9	8.12	778	22.0
	03/02/05	1.36	74	6.78	1,240	22.0
MWB019	05/07/04	3.67	163	7.71	330	24.3
	07/15/04	375	187	7.52	2,650	23.1
	09/21/04	3.53	165	7.41	3,300	24.1
	12/20/04	4.65	67	7.51	3,330	23.3
	03/02/05	3.79	63	6.76	2,850	23.2
MWC015	05/06/04	0	13	6.77	921	24.1
	07/16/04	0	-108	6.5	873	22.9
	09/23/04	0.7	-234	7.45	740	23.2
	12/21/04	1.1	-69	6.92	840	22.6
	03/07/05	0	15	7.14	762	22.4
MWC016	05/06/04	11.61	86	7.13	1,210	23.2
	07/16/04	8.05	207	8.22	1,180	22.6
	09/23/04	8.51	166	8.13	1,150	23.1
	12/21/04	7.02	43	8.47	1,140	22.5
	03/04/05	6.34	184	7.02	1,240	22.4
MWC017	05/07/04	3.6	121	8.31	1,000	24.0
	07/16/04	5.56	112	7.92	736	22.8
	09/22/04	1.94	-138	6.81	779	23.4
	12/21/04	1.67	-237	6.97	784	23.6
	03/02/05	2.79	-178	7.17	786	22.8
MWC021	05/07/04	0.18	10	7.41	798	25.9
	07/15/04	0	-41	8.13	807	22.7
	09/21/04	0	-182	6.61	869	23.3
	12/20/04	2.43	-241	8.36	825	23.0
	03/01/05	2.64	-254	7.58	910	23.0
TMW_01	09/18/02	2.98	63	7.32	3,340	23.6
	03/27/03	6.62	80	6.65	5,370	23.5
	09/24/03	3.63	36	6.71	4,880	22.8
	03/25/04	0	81	6.38	5,860	23.2
	09/23/04	0.91	254	6.52	1,000	23.2
TMW_02	03/28/03	11.59		6.94	2,690	22.8
	09/24/03	0	-202	6.6	3,340	22.7
	03/25/04	0	-169	6.88	3,260	23.4
	09/24/04	0	-155	6.5	5,700	24.0
TMW_04	09/18/02	6.17	82	7.43	1,960	24.8
	03/27/03	5.1	113	6.58	1,410	22.4
	09/24/03	5.13	108	7	1,650	22.7
	03/25/04	0	99	6.7	1,720	23.6

Table 2

Historical Monitored Natural Attenuation Parameters

Boeing Realty Corporation, Former C-6 Facility
Los Angeles, California

Well I.D.	Monitoring Date	Dissolved Oxygen (mg/L)	Oxidation Reduction Potential (mV)	pH	Conductivity (uS/cm)	Temperature (°C)
	09/23/04	0.51	23	6.3	1,720	23.9
TMW_05	09/18/02	4.57	71	7.53	1,310	23.8
	03/28/03	10.46	152	7.58	650	21.8
TMW_06	09/18/02	4.52	89	7.5	1,930	22.8
	03/26/03	6.07	120	7.42	1,610	22.8
	09/24/03	4.75	38	7.02	1,720	22.2
	03/23/04	0.42	65	6.74	1,650	23.2
	09/22/04	1.6	107	7.96	1,800	22.3
	03/02/05	3.2	67	7.19	1,280	23.0
TMW_07	09/18/02	3.78	90	7.5	1,920	24.4
	03/27/03	6.06	151	6.61	1,610	23.5
	09/24/03	3.22	92	7.01	1,820	24.6
	03/24/04	1.13	83	7.14	1,910	23.7
	09/23/04	1.3	172	7.84	1,920	31.0
TMW_08	03/28/03	12.51		7.06	1,650	23.1
	03/25/04	0	-168	6.52	1,830	23.9
TMW_09	03/26/03	5.66	124	7.45	1,520	23.6
	03/24/04	0	22	9.8	1,620	23.7
TMW_10	09/16/02	4.45	50	7.33	1,890	24.7
	03/26/03	5.34	66	7.08	1,570	23.5
	09/23/03	3.92	50	7.03	1,760	23.4
	03/22/04	2.18	64	7.22	1,920	23.2
	09/21/04	1.74	54	6.03	1,840	23.7
	03/01/05	1.58	6	7.17	2,060	24.5
TMW_11	09/17/02	2.76	63	7.08	1,920	25.1
	03/26/03	4.46	54	7.05	1,650	23.7
	09/23/03	2.34	30	6.82	1,920	24.2
	03/23/04	0.79	83	6.98	1,970	24.0
	09/21/04	1.15	-2	6.51	1,650	26.0
	03/01/05	1.13	25	6.84	2,000	25.7
TMW_14	09/16/02	5.64	79	7.06	3,370	24.7
	03/26/03	5.57	64	6.97	3,400	23.8
	09/23/03	5.59	78	6.7	3,900	23.2
	03/22/04	53	62	6.46	4,710	24.0
	09/21/04	1.08	38	6.6	3,310	23.5
	03/01/05	2.81	64	6.79	4,030	23.7
TMW_15	09/17/02	4.49	-5	7.44	1,400	24.9
	03/26/03	4.34	7	7.22	1,170	24.3
	09/23/03	3.02	-82	7.11	1,310	23.3
	03/22/04	0	-80	6.8	1,120	24.0
	09/20/04	0.46	29	6.72	1,200	24.3
	09/22/04	0.89	30	6.64	1,340	24.5
	03/02/05	3.05	29	7.17	1,330	24.3
WCC_03S	03/25/02	0.1	-182	6.61	2,860	23.9

Table 2

Historical Monitored Natural Attenuation Parameters

Boeing Realty Corporation, Former C-6 Facility
Los Angeles, California

Well I.D.	Monitoring Date	Dissolved Oxygen (mg/L)	Oxidation Reduction Potential (mV)	pH	Conductivity (uS/cm)	Temperature (°C)
WCC_04S	03/27/03	4.99	-85	6.51	1,350	26.6
	03/24/04	0	-184	6.77	1,990	23.1
	03/26/02	8.13	35	7.9	2,560	23.5
	03/26/02	5.35	42	7.9	2,500	23.5
	03/26/02	3.63	-11	7.98	1,990	23.5
	03/24/04	0	-53	9.33	1,750	23.6
	03/07/05	0	-97	7.03	3,090	23.9
WCC_05S	03/21/02	4.86	61	6.98	1,370	23.2
	09/16/02	5.02	74	7.05	1,930	23.6
	03/25/03	3.65	38	7.35	1,130	23.1
	09/23/03	4.73	103	6.86	1,790	22.8
	03/22/04	1.78	81	7.04	1,840	23.4
	09/20/04	1.55	94	6.4	1,640	23.5
	03/01/05	0	-155	6.85	217	20.8
WCC_06S	03/26/02	2.12	-137	7.89	2,200	24.0
	03/25/03	3.16	-208	7.06	1,710	23.4
	03/24/04	0	-218	9.56	1,220	23.4
WCC_07S	03/25/02	4.03	55	7.16	1,230	23.5
	03/28/03	9.63	175	7.32	1,790	21.3
	03/03/05	2.92	77	6.84	1,610	23.1
WCC_09S	03/22/02	3.09	55	7.04	1,340	23.3
	03/26/03	4.15	15	7.29	1,580	23.1
	03/23/04	0.41	55	6.64	1,220	23.1
	03/02/05	4.08	48	7.3	1,160	23.3
WCC_12S	03/25/02	4.8	61	7.18	1,210	23.6
XMW-09	03/21/02	0.25	36	6.6	1,810	23.5
	03/25/04	0	53	6.86	2,090	23.1
	03/03/05	0	74	6.34	2,240	23.1
XMW_19	03/22/02	4.39	24	7.04	1,560	23.5
	03/28/03	12.38	142	7.29	1,650	23.6
	03/22/04	0.66	-4	6.86	19	23.5
	03/03/05	0	12	7.03	222	23.4

Table 3

Estimated Mass of TCE and 1,1-DCE in Groundwater
Boeing Realty Corporation, Former C-6 Facility
Los Angeles, California

	Area ¹ (feet ²)		Volume of Water ² (feet ³)		Volume of Water (L)		Average Concentration ³ (ug/L)	Mass (lb)	
	B-Sand	C-Sand	B-Sand	C-Sand	B-Sand	C-Sand		B-Sand	C-Sand
TCE conc.									
10,000	30,310	--	250,058	--	7,081,628	--	10,000	156	--
5,000	185,369	--	1,529,294	--	43,309,613	--	7,071	674	--
1,000	734,294	556,128	6,057,926	2,836,253	171,560,450	80,322,679	2,236	844	395
100	1,066,959	914,540	8,802,412	4,664,154	249,284,301	132,088,841	316	173	92
							Subtotal	1,847	487
1,1-DCE conc.									
10,000	6654	--	54,896	--	1,554,641	--	10,000	34	--
1,000	75780	--	625,185	--	17,705,239	--	3162	123	--
100	273190	187845	2,253,818	958,010	63,828,112	27,130,829	316	44	19
10	368968	447409	3,043,986	2,281,786	86,205,684	64,620,177	31.6	6	4
							Subtotal	208	23
							Total Mass	2,055	510

¹ Areas based on plumes presented in Figures 13, 14, 16, and 17

² Volume calculations assume an average saturated thickness in B-Sand and C-Sand of 27.5 and 17 feet, respectively and a porosity of 0.3

³ Average concentrations based on log scale

Table 4

Anticipated Schedule for Remedial Alternative 1
Boeing Realty Corporation, Former C-6 Facility
Los Angeles, California

Remedial Scenarios	2005	2006	2007	2008	2009	2010
Regional Remedy						
a. Pilot Test/Evaluation	■	■				
b. Design		■	■			
c. Construction				■	■	
d. Phased/Intermittent Operation		■	■	■	■	
e. Full-Scale Operation						■
C-6 Remedial Alternative 1						
a. EISB						
- Construction	■					
- Operation		■	■	■	■	
b. Performance Monitoring	■	■	■	■	■	
c. Bioaugmentation			■	■	■	
d. Hydraulic Containment						
B- and C- Sands		■	■	■	■	■
Gage Aquifer		■	■	■	■	■
e. Chemical Oxidation				■	■	■

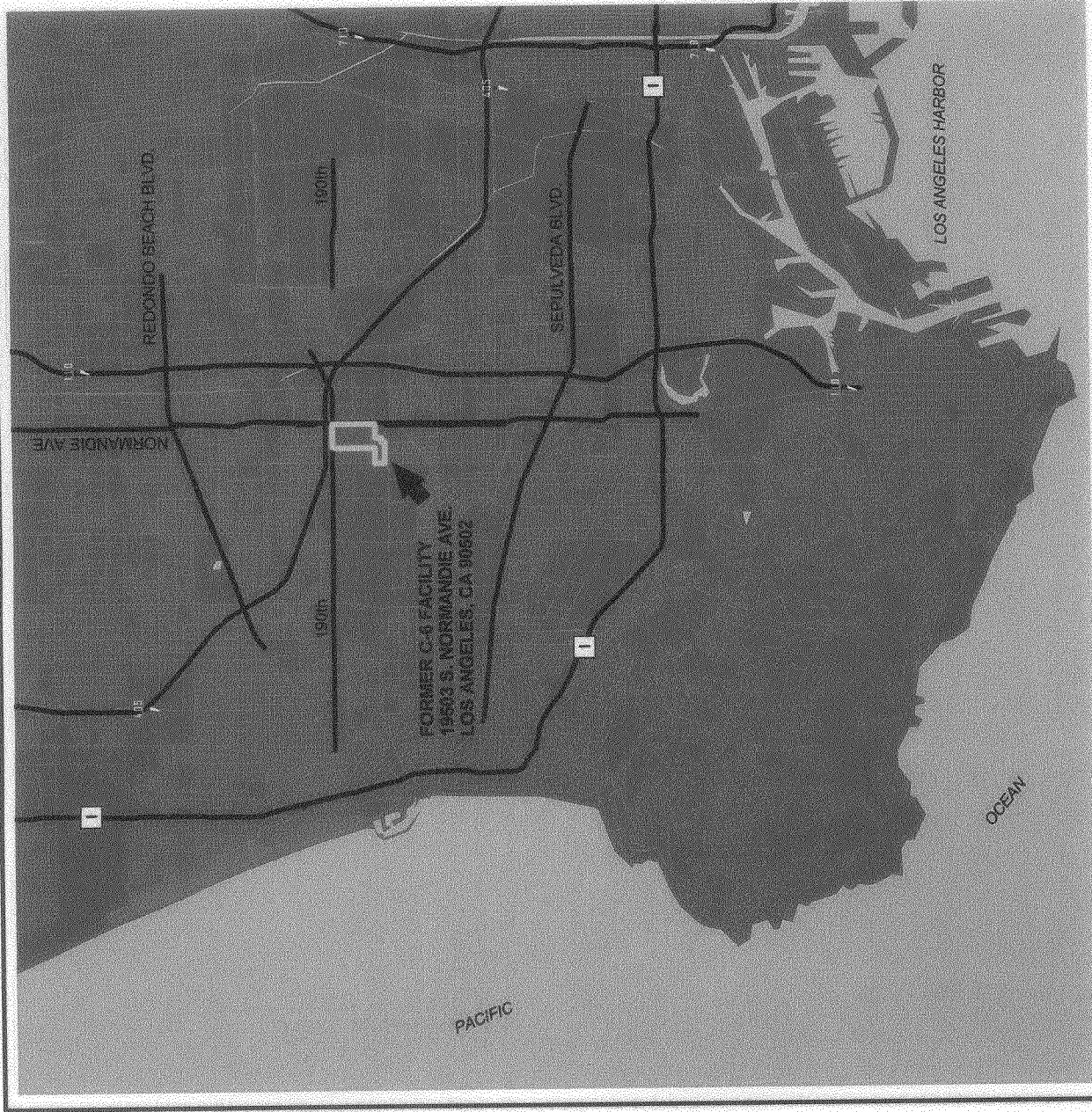
Table 5


Capture Zone Input Parameters
Boeing Realty Corporation, Former C-6 Facility
Los Angeles, California

Parameter	Symbol	Value	Units	Reference
<i>B-SAND</i>				
Regional Flow Hydraulic Gradient	i	0.0010		Haley & Aldrich, 2004
Regional Flow Direction	α	South		Haley & Aldrich, 2004
Aquifer Thickness	b	27.5	feet	Haley & Aldrich, 2002
Hydraulic Conductivity	k	20	ft/day	CH2M Hill, 2004
Porosity	η	0.3		Assumed
Seepage Velocity	v_s	24.3	feet/yr	Calculated ¹
Number of wells		8		
Extraction rate per well		3	gpm	
Total extraction rate		24	gpm	
<i>C-SAND</i>				
Regional Flow Hydraulic Gradient	i	0.0010		March 2004 water levels
Regional Flow Direction	α	S17°E		Haley & Aldrich, 2004
Aquifer Thickness	b	17	feet	Haley & Aldrich, 2002
Hydraulic Conductivity	k	145	ft/day	CH2M Hill, 2004
Porosity	n	0.3		Assumed
Seepage Velocity	v_s	176	feet/yr	Calculated
Number of wells		6		
Extraction rate per well		10	gpm	
Total extraction rate		60	gpm	

¹ Seepage velocity calculated as $v_s = ki/n$

Figures

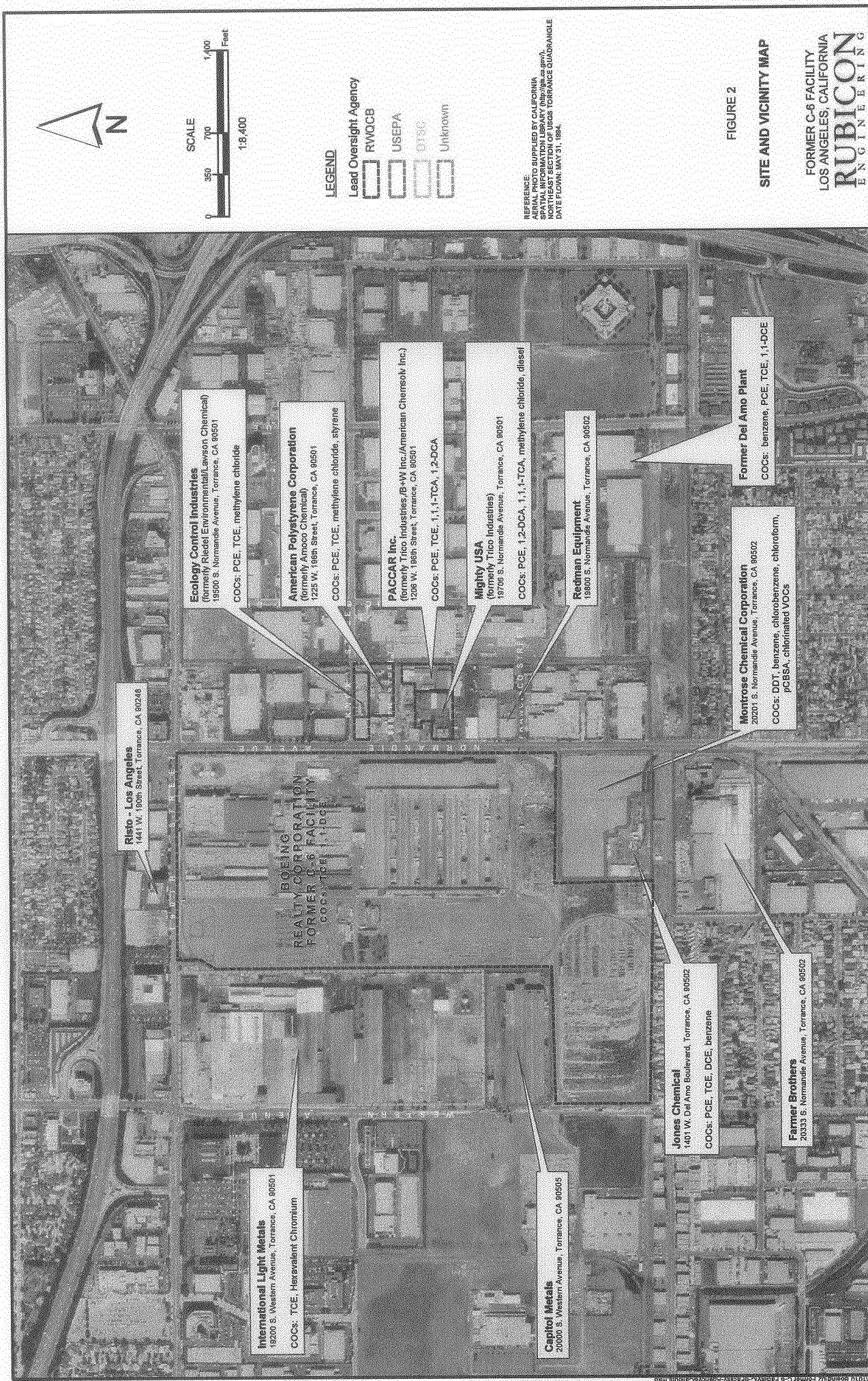


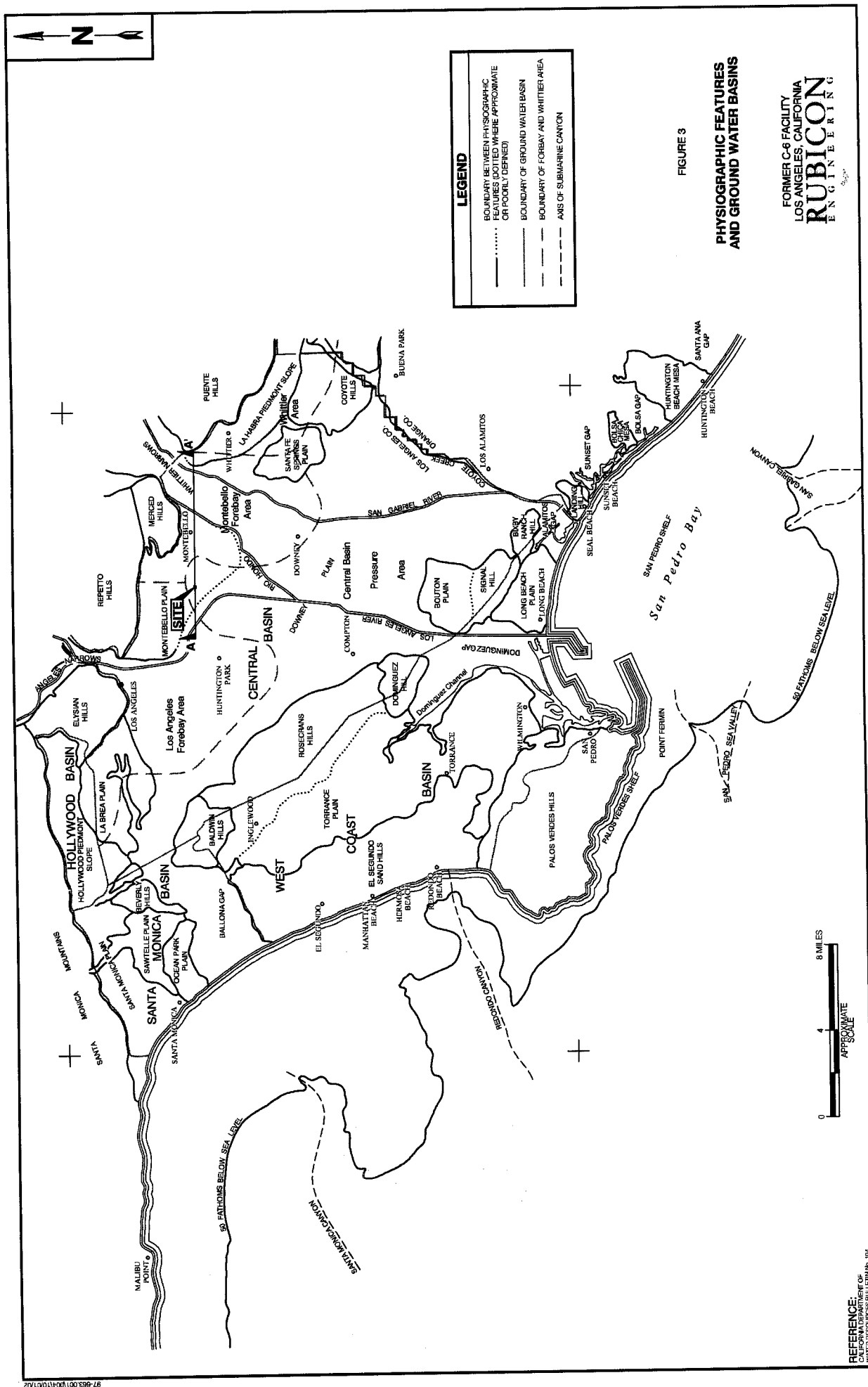
EXPLANATION
 BOEING REALTY CORPORATION: FORMER C-6 FACILITY

REFERENCE:
Base map downloaded from "Tiger File" data website hosted by ESRI.



FIGURE 1
SITE LOCATION MAP
FORMER C-6 FACILITY
LOS ANGELES, CALIFORNIA
RUBICON
ENGINEERING





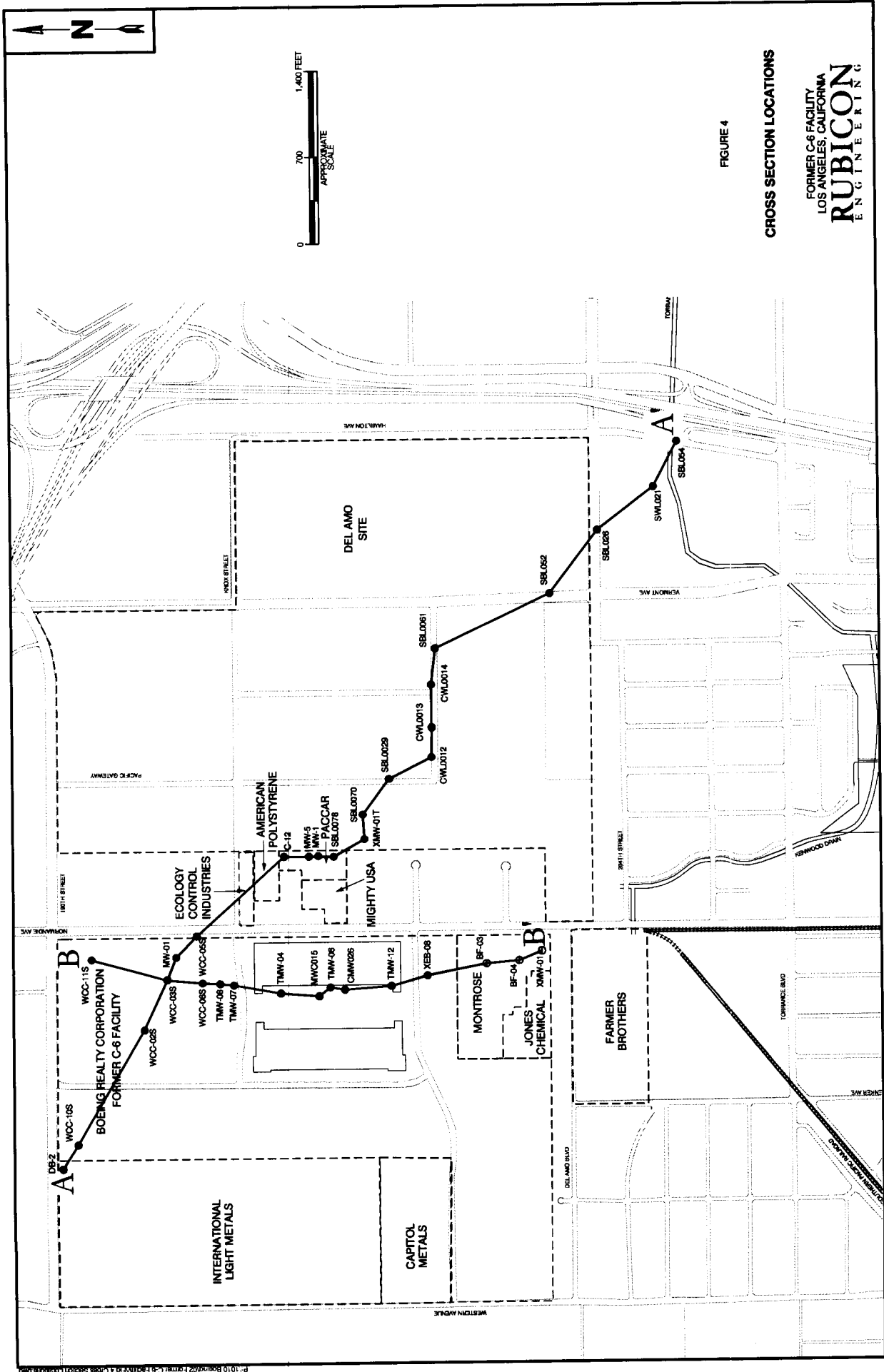


FIGURE 4

CROSS SECTION LOCATIONS

FORMER C-6 FACILITY
LOS ANGELES, CALIFORNIA
RUBICON
ENGINEERING

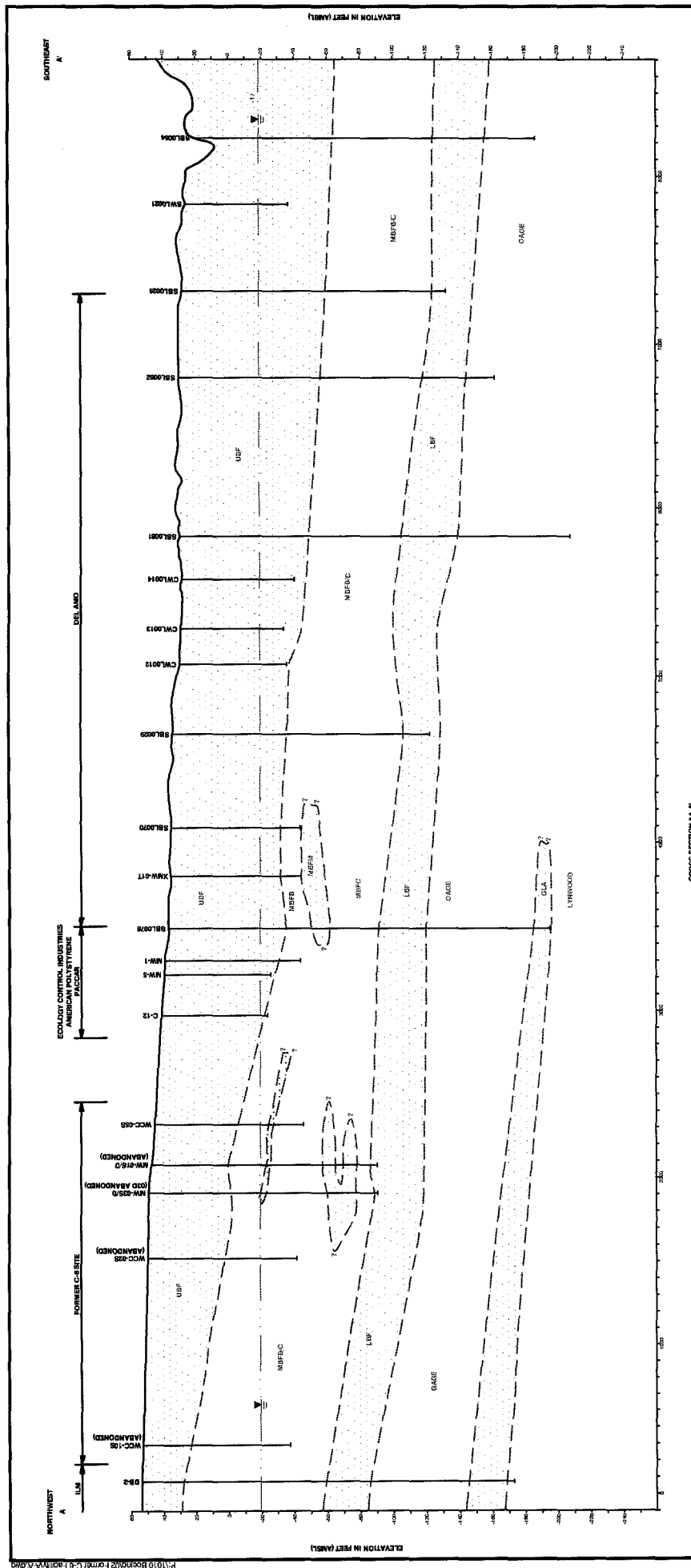


FIGURE 5

HYDROSTRATIGRAPHIC SECTION A-A'

FORMER C-6 FACILITY
LOS ANGELES, CALIFORNIA
RUBICON
ENGINEERING

LEGEND

- LEGEND**
- BOREHOLE OR MONITORING WELL AND NAME
- INTERPRETED HYDROSTRATIGRAPHIC UNIT BOUNDARY
- PREDOMINANTLY FINE-GRAINED STRATA
- PREDOMINANTLY COARSE-GRAINED STRATA

HYDROSTRATIGRAPHIC UNITS

- | UNIT | THINNING FACTOR |
|---------|---------------------------|
| MBFB | UPPER BELLFLOWER AQUITARD |
| MBFM | MIDDLE BELLFLOWER B SAND |
| MBFC | MIDDLE BELLFLOWER MUD |
| LBFB | MIDDLE BELLFLOWER C SAND |
| GAGE | LOWER BELLFLOWER AQUITARD |
| GLA | GAGE AQUIFER |
| LYNWOOD | GAGE-LYNWOOD AQUITARD |
| | LYNWOOD AQUIFER |

NOTE: CROSS SECTION ADAPTED FROM KENNEDY/JENKS CONSULTANTS GROUND WATER STATUS REPORT, OCTOBER 2000 AND ENGLAND GEOSYSTEM INC. DRAFT FEASIBILITY EVALUATION, JULY 2001.

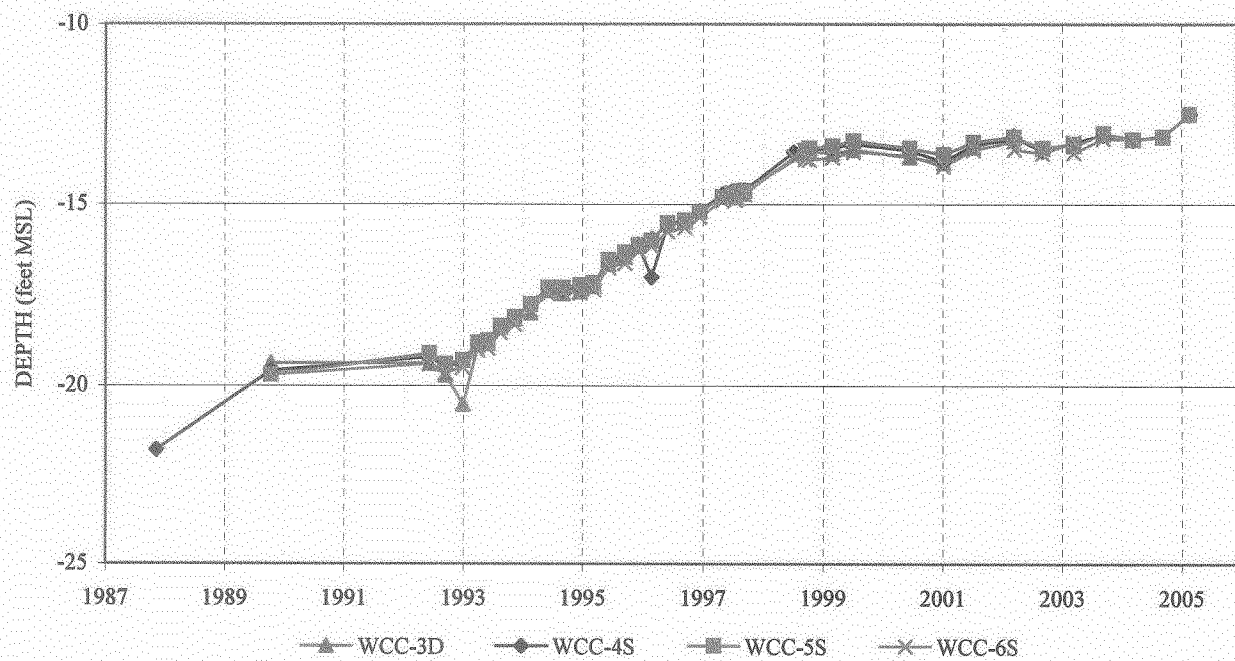
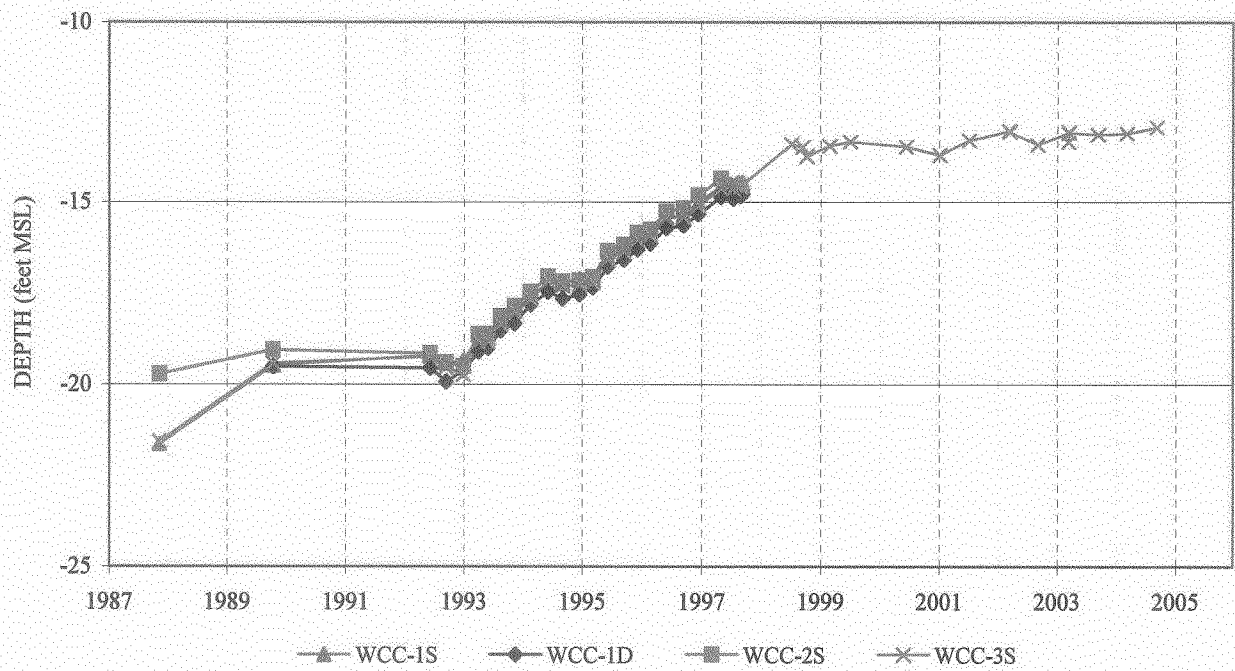


FIGURE 7

HYDROGRAPHS OF
GROUNDWATER WELLS
WCC-1S through WCC-6S

FORMER C-6 FACILITY
LOS ANGELES, CALIFORNIA

RUBICON
ENGINEERING

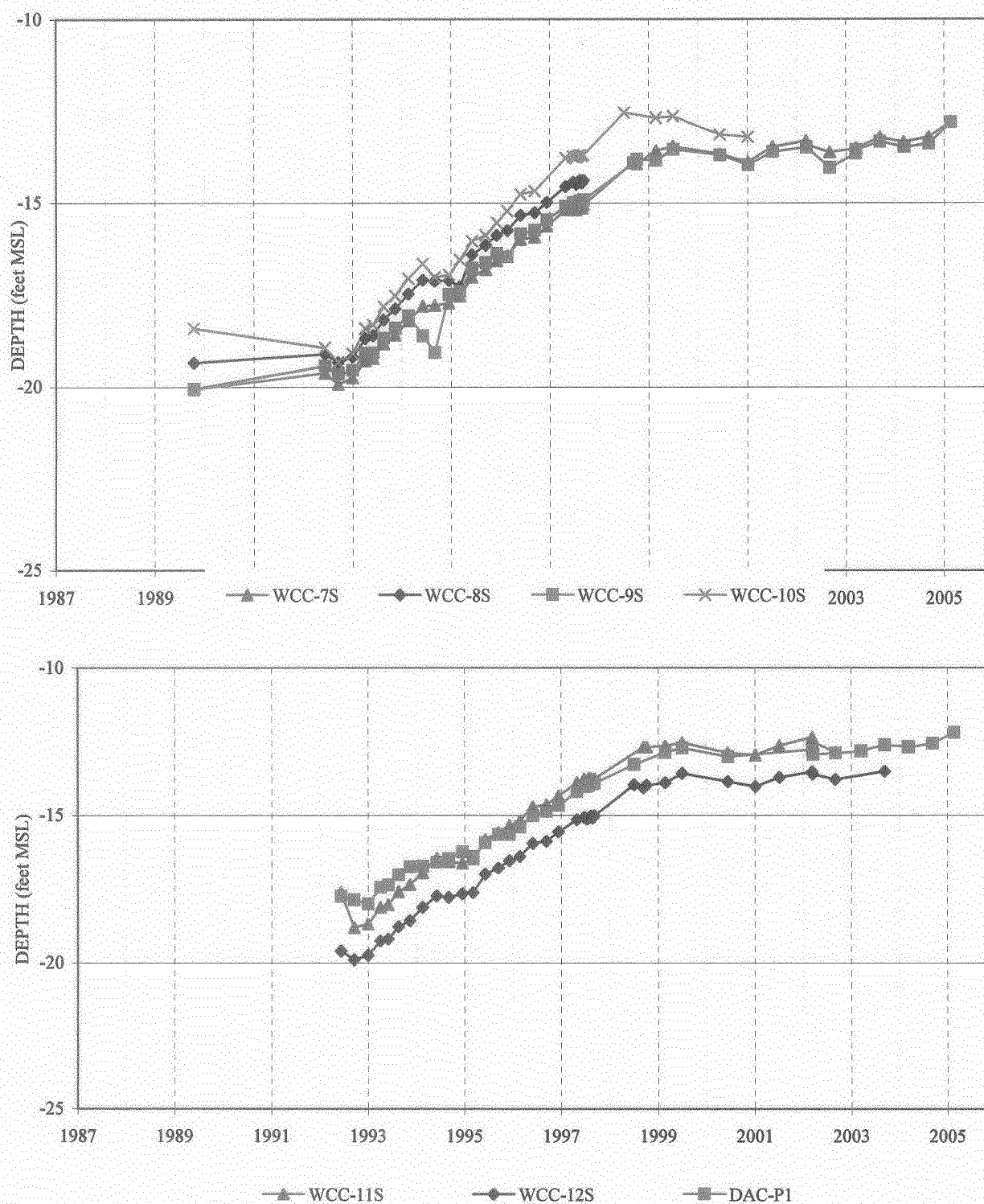
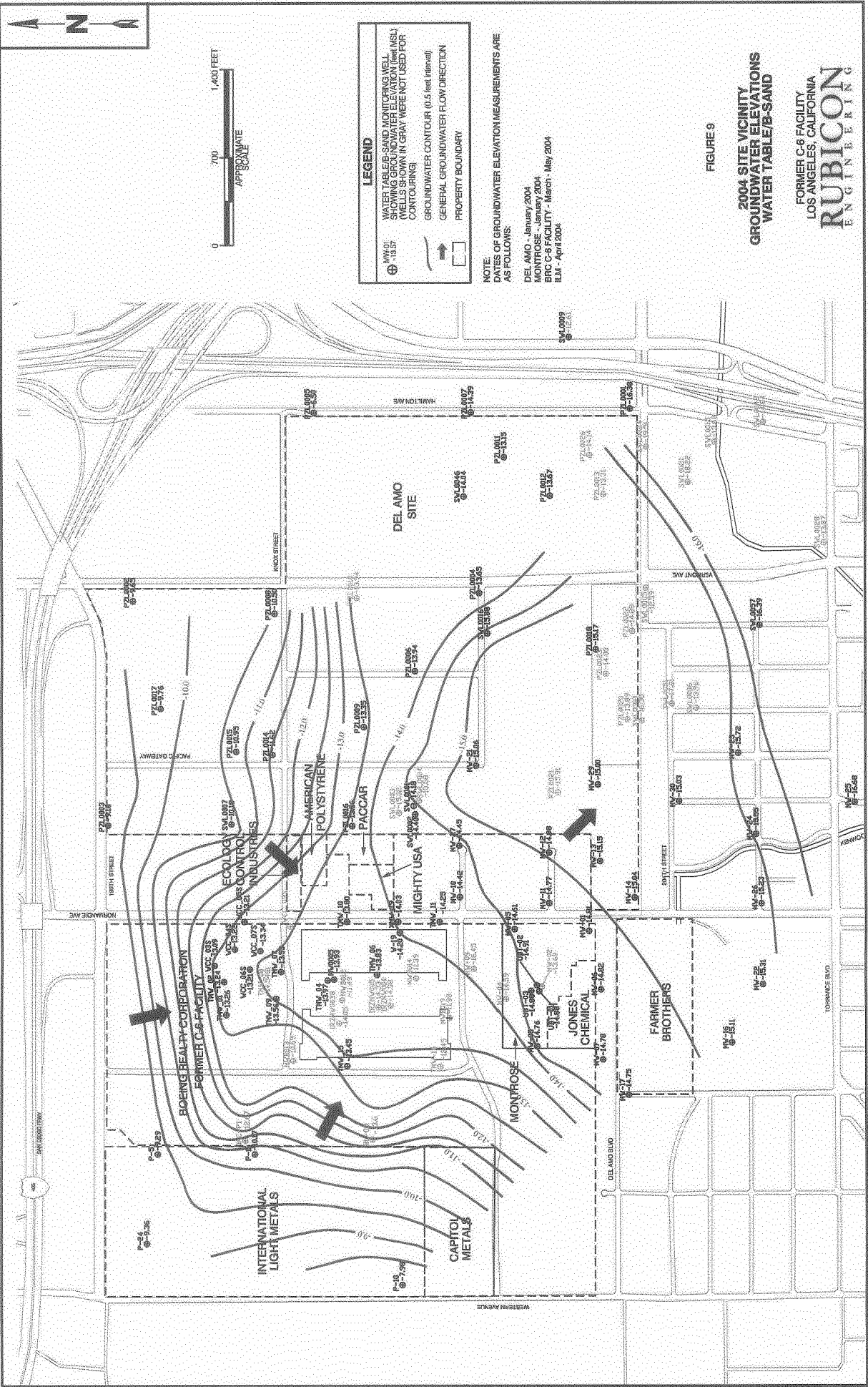
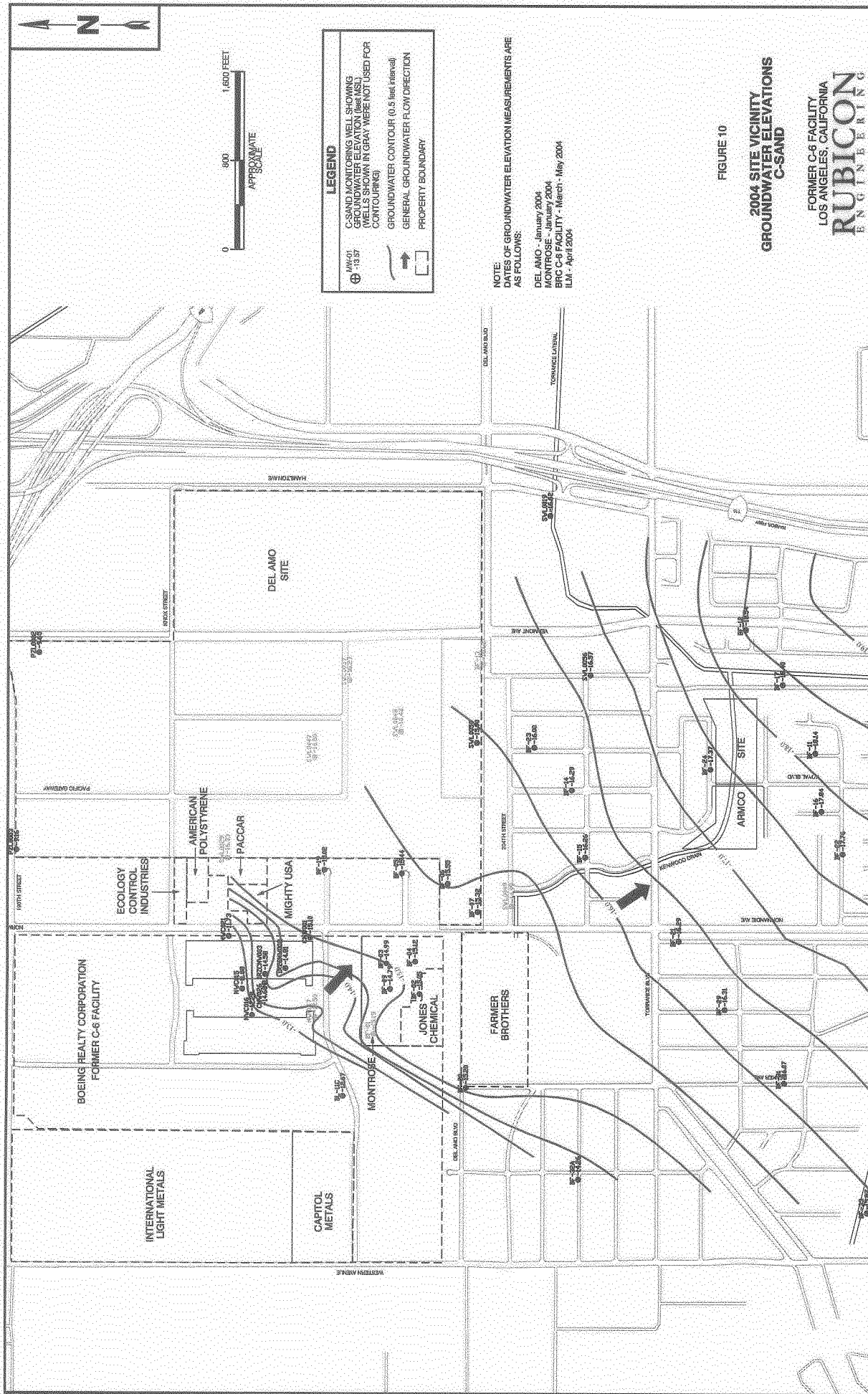
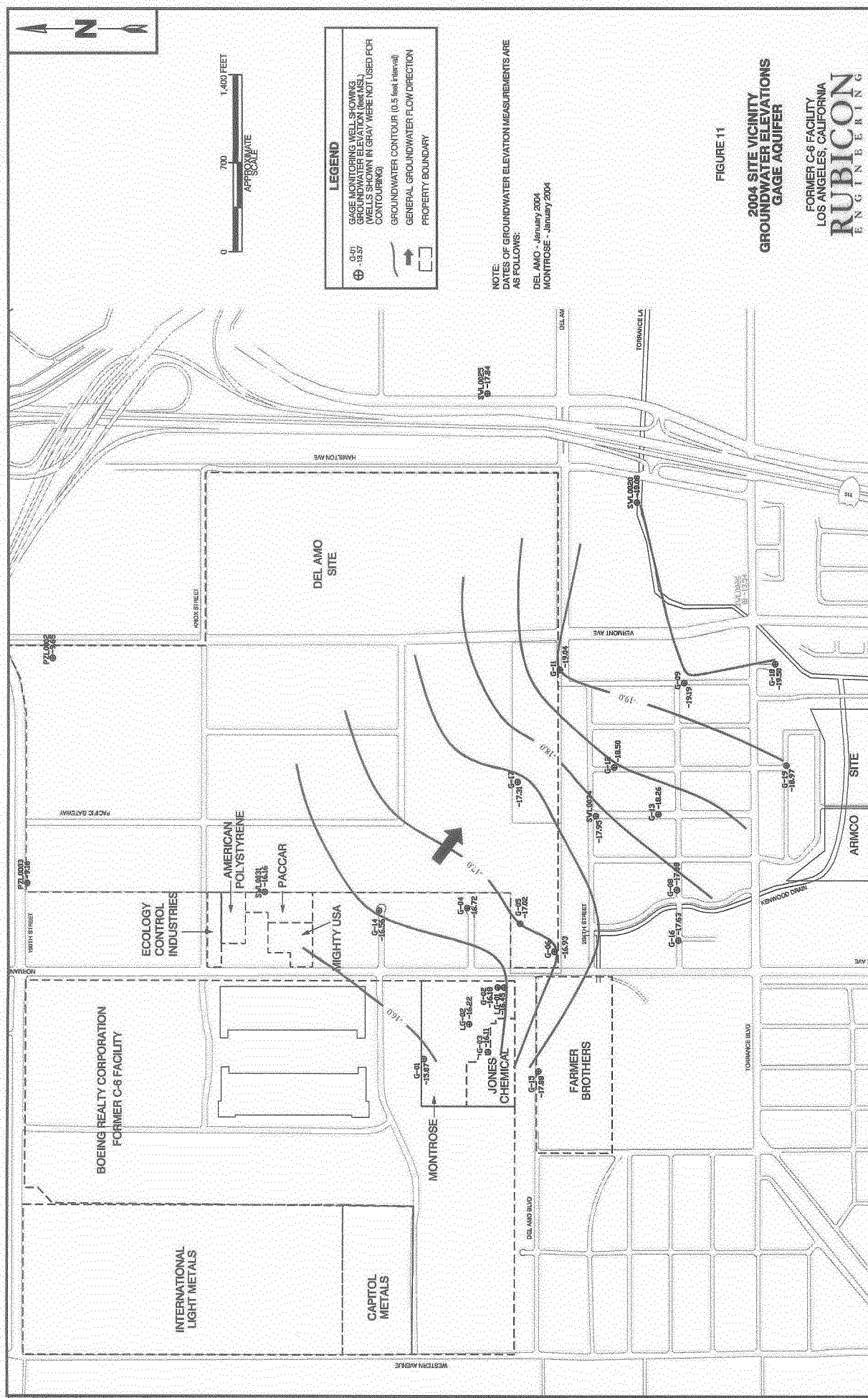


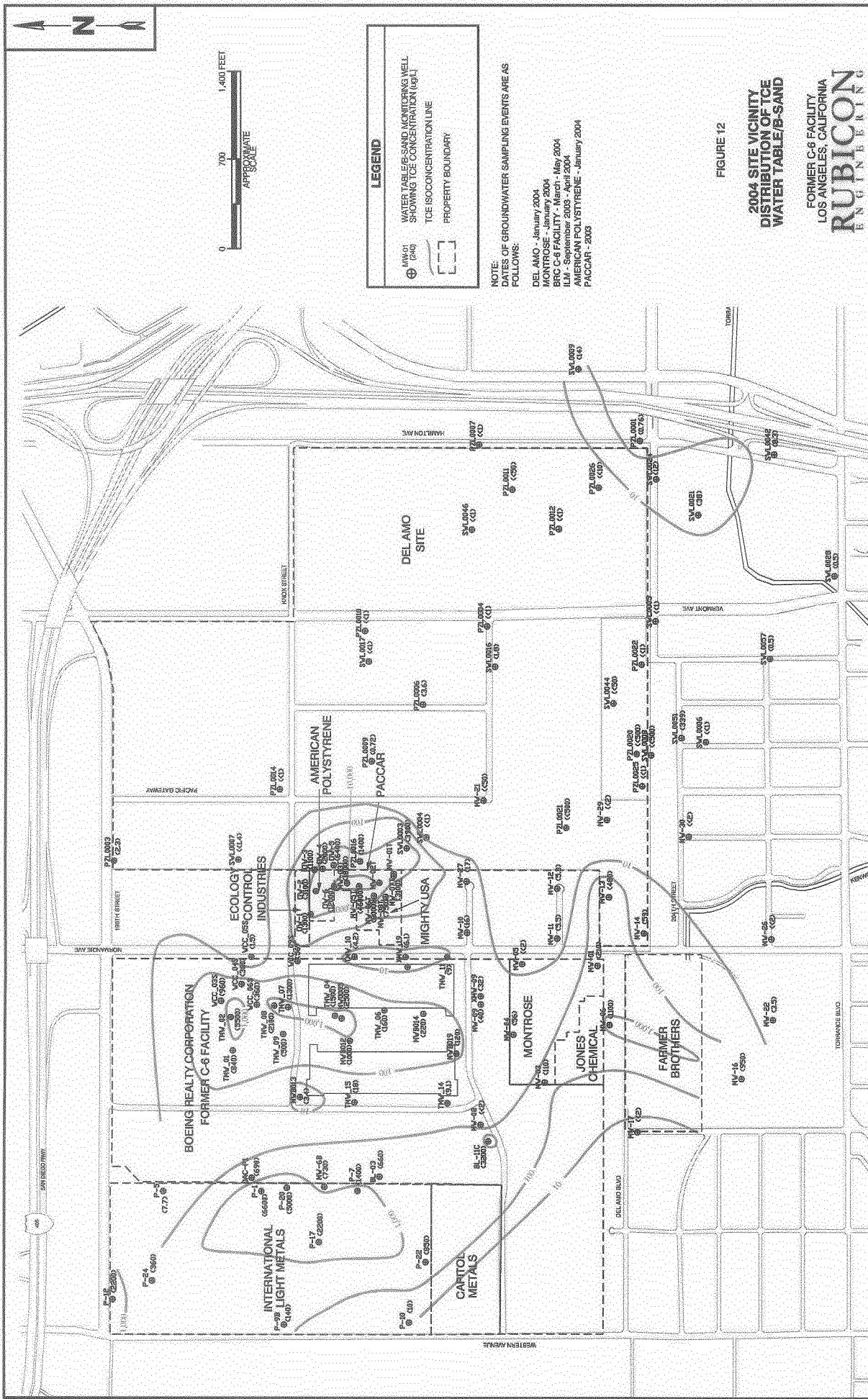
FIGURE 8
HYDROGRAPHS OF
GROUNDWATER WELLS
WCC-7S through WCC-12S, & DAC-P1

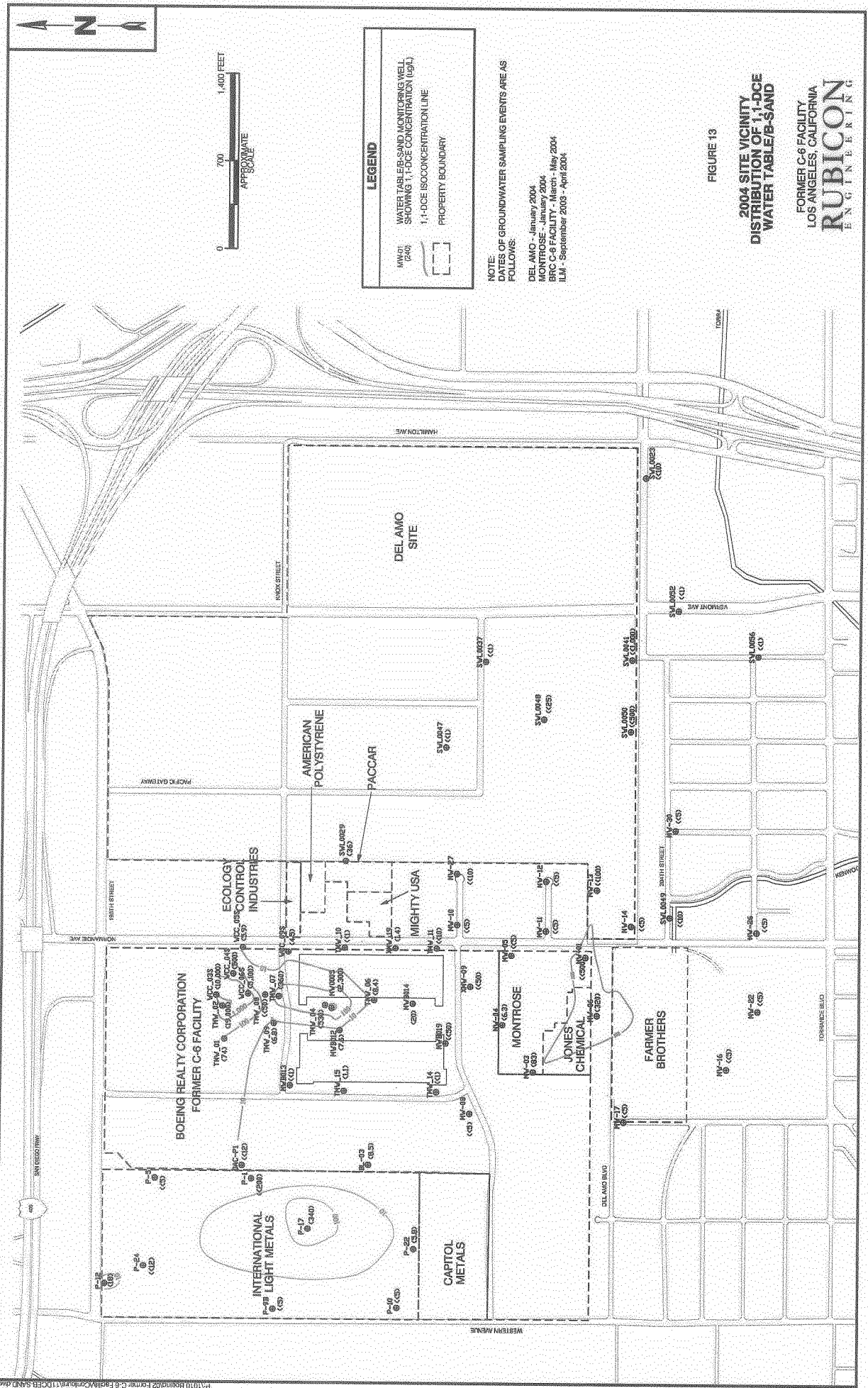
FORMER C-6 FACILITY
LOS ANGELES, CALIFORNIA
RUBICON
ENGINEERING

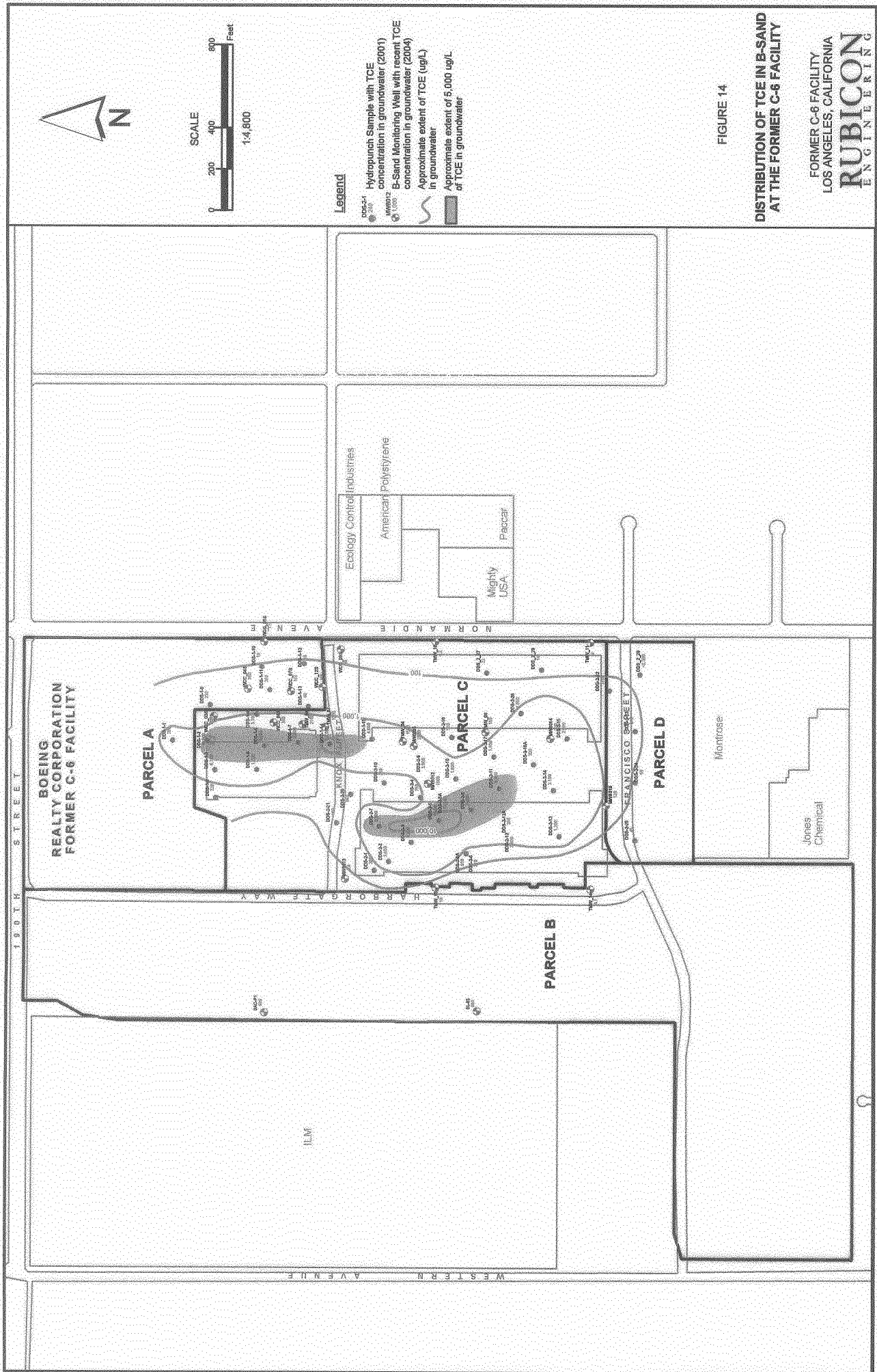


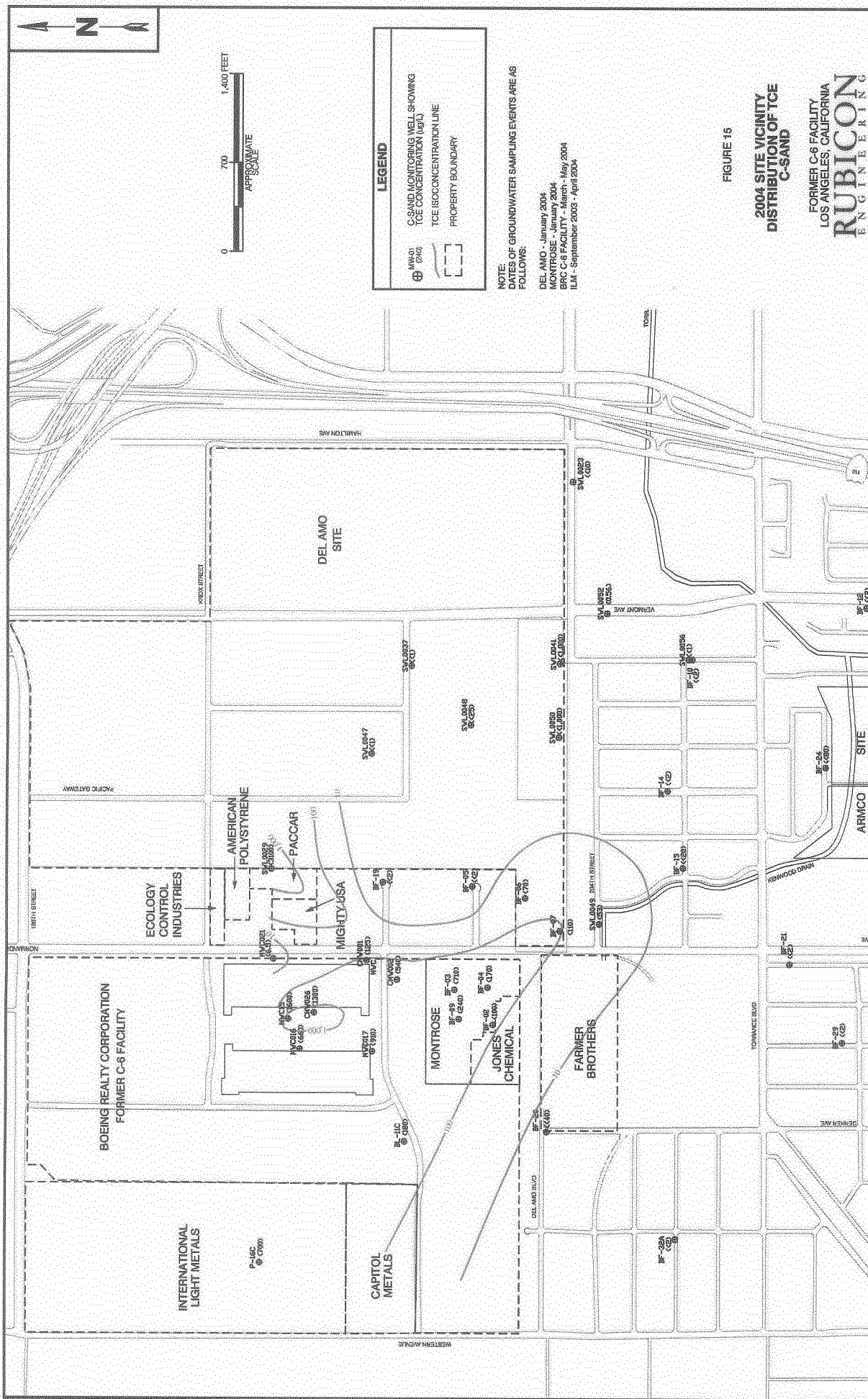


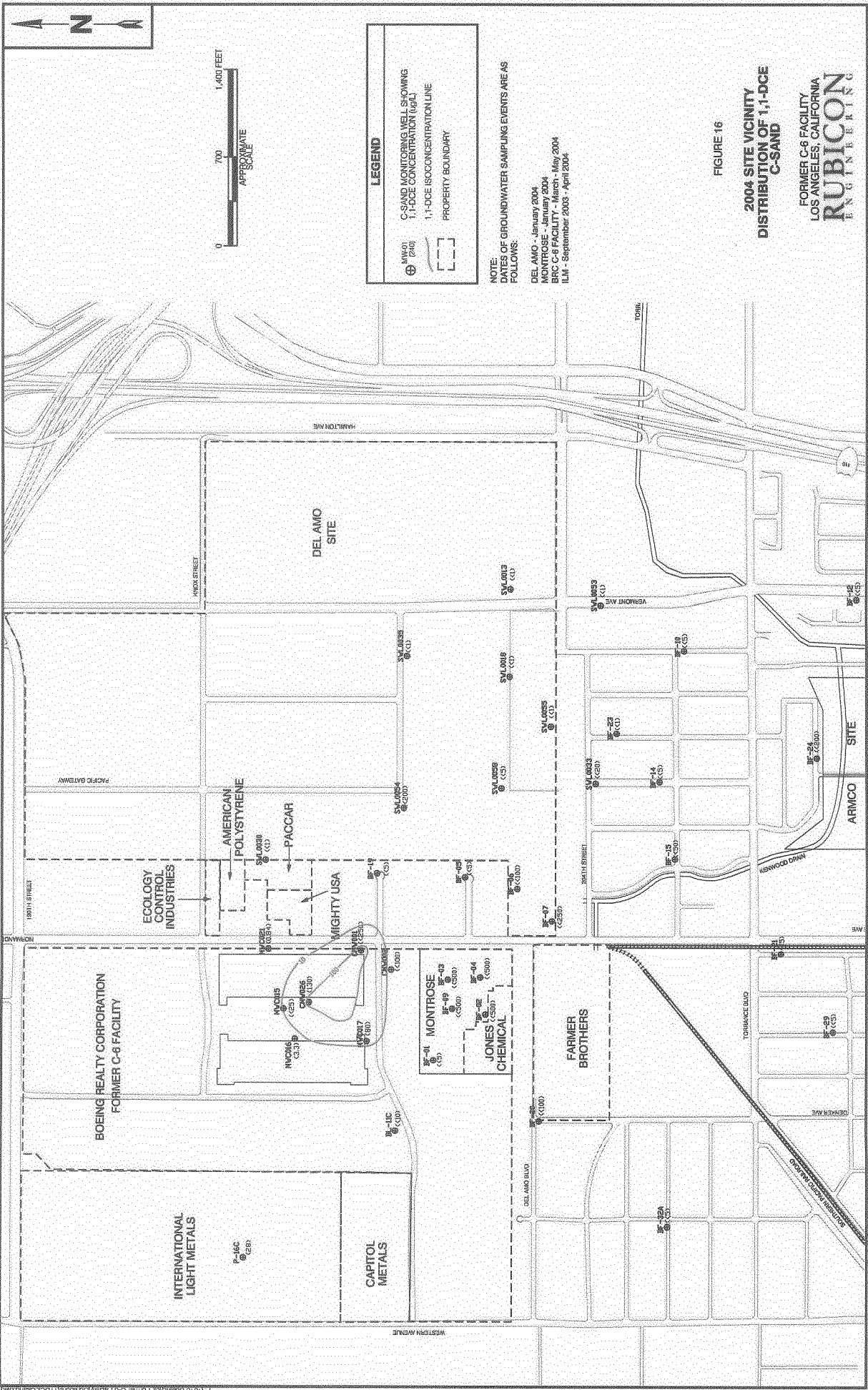


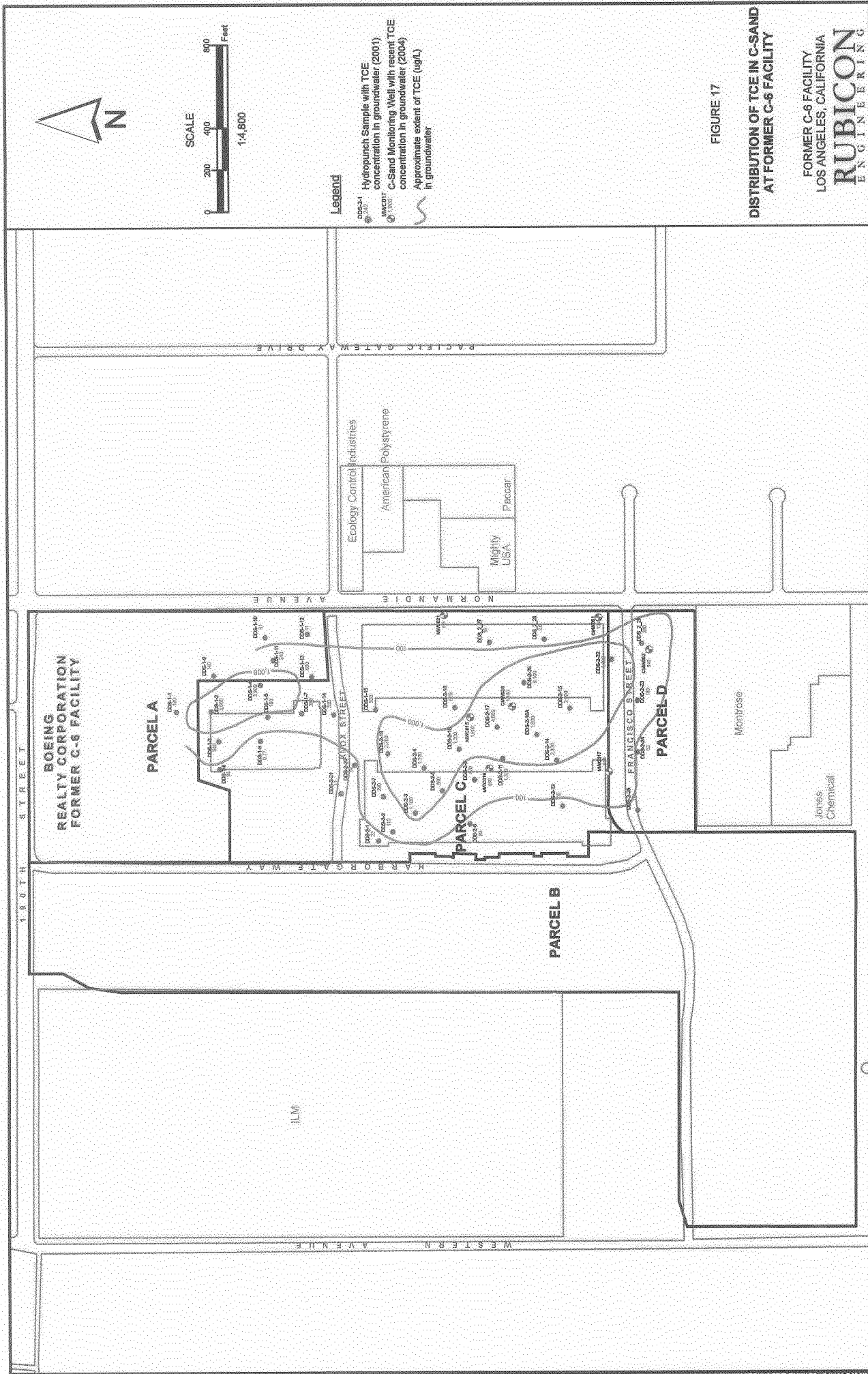


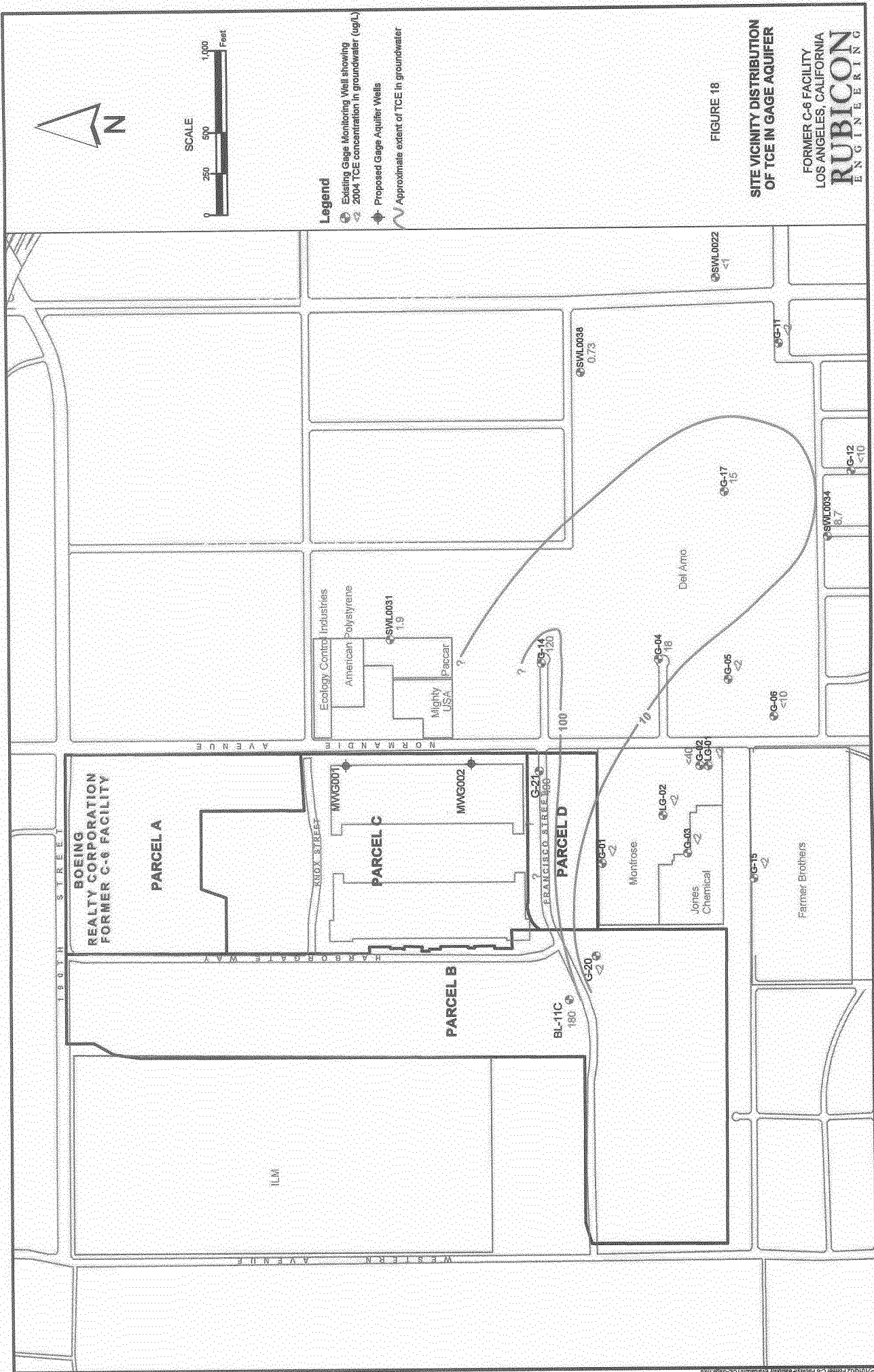












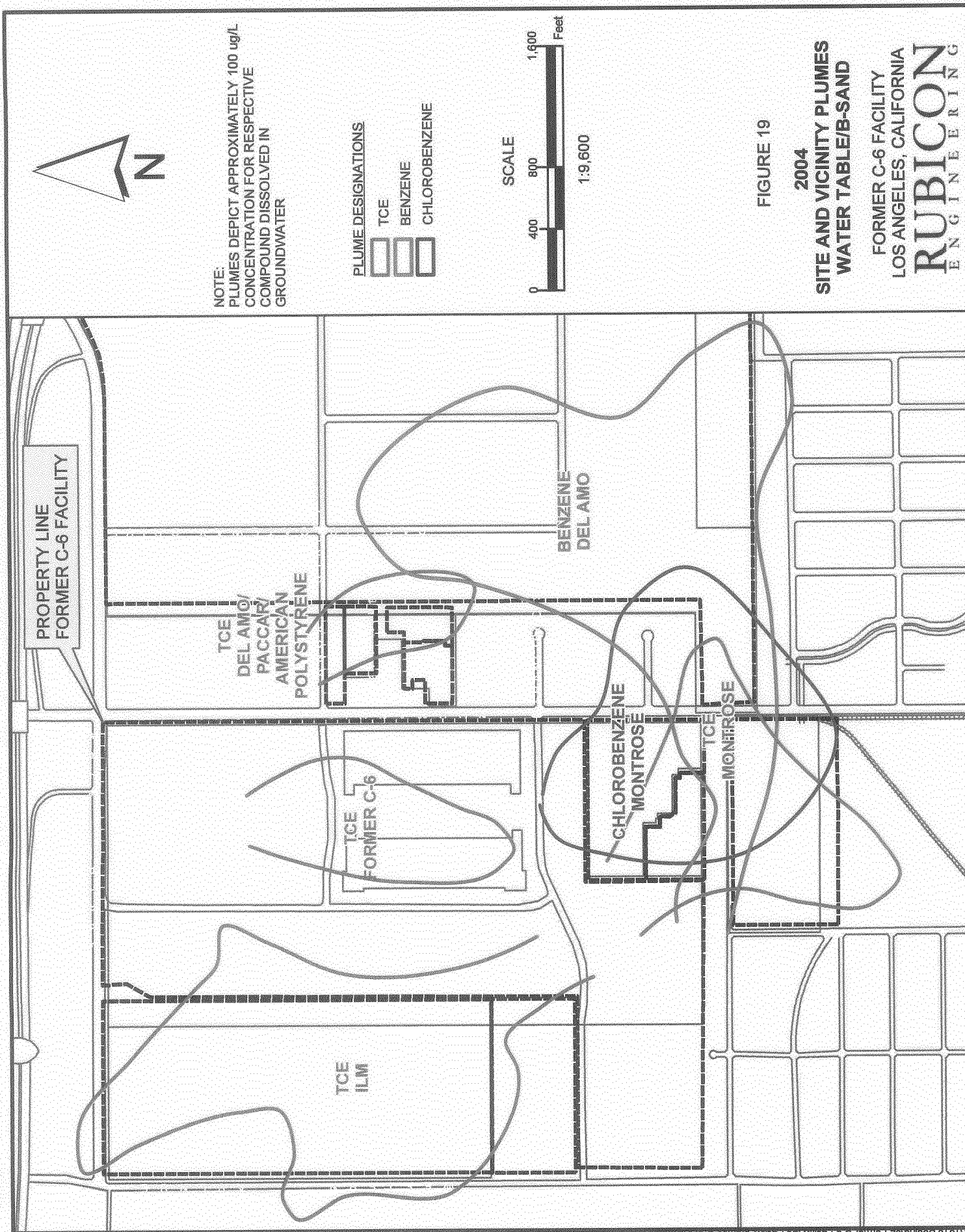


FIGURE 19

2004

**SITE AND VICINITY PLUMES
WATER TABLE/B-SAND**

FORMER C-6 FACILITY
LOS ANGELES, CALIFORNIA

RUBICON
ENGINEERING

PROPERTY LINE
FORMER C-6 FACILITY

TCE
ILM

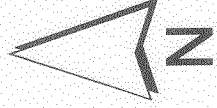
TCE
FORMER C-6

TCE
MONTROSE

TCE
DELANO

BENZENE
DELANO

CHLOROBENZENE
MONTROSE



NOTE:
PLUMES DEPICT APPROXIMATELY 100 ug/L
CONCENTRATION FOR RESPECTIVE
COMPOUND DISSOLVED IN
GROUNDWATER

PLUME DESIGNATIONS

- TCE
- BENZENE
- CHLOROBENZENE

SCALE



1:9,600

FIGURE 20

2004

SITE AND VICINITY PLUMES
C-SAND

FORMER C-6 FACILITY
LOS ANGELES, CALIFORNIA

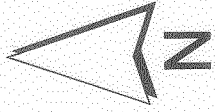
RUBICON
ENGINEERING

PROPERTY LINE
FORMER C-6 FACILITY

TCE
ILM

TCE
FROM ?

CHLOROBENZENE
MONTROSE



NOTE:
PLUMES DEPICT APPROXIMATELY 100 ug/L
CONCENTRATION FOR RESPECTIVE
COMPOUND DISSOLVED IN
GROUNDWATER

PLUME DESIGNATIONS



SCALE

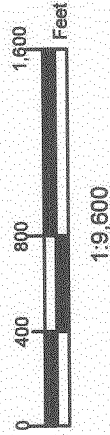


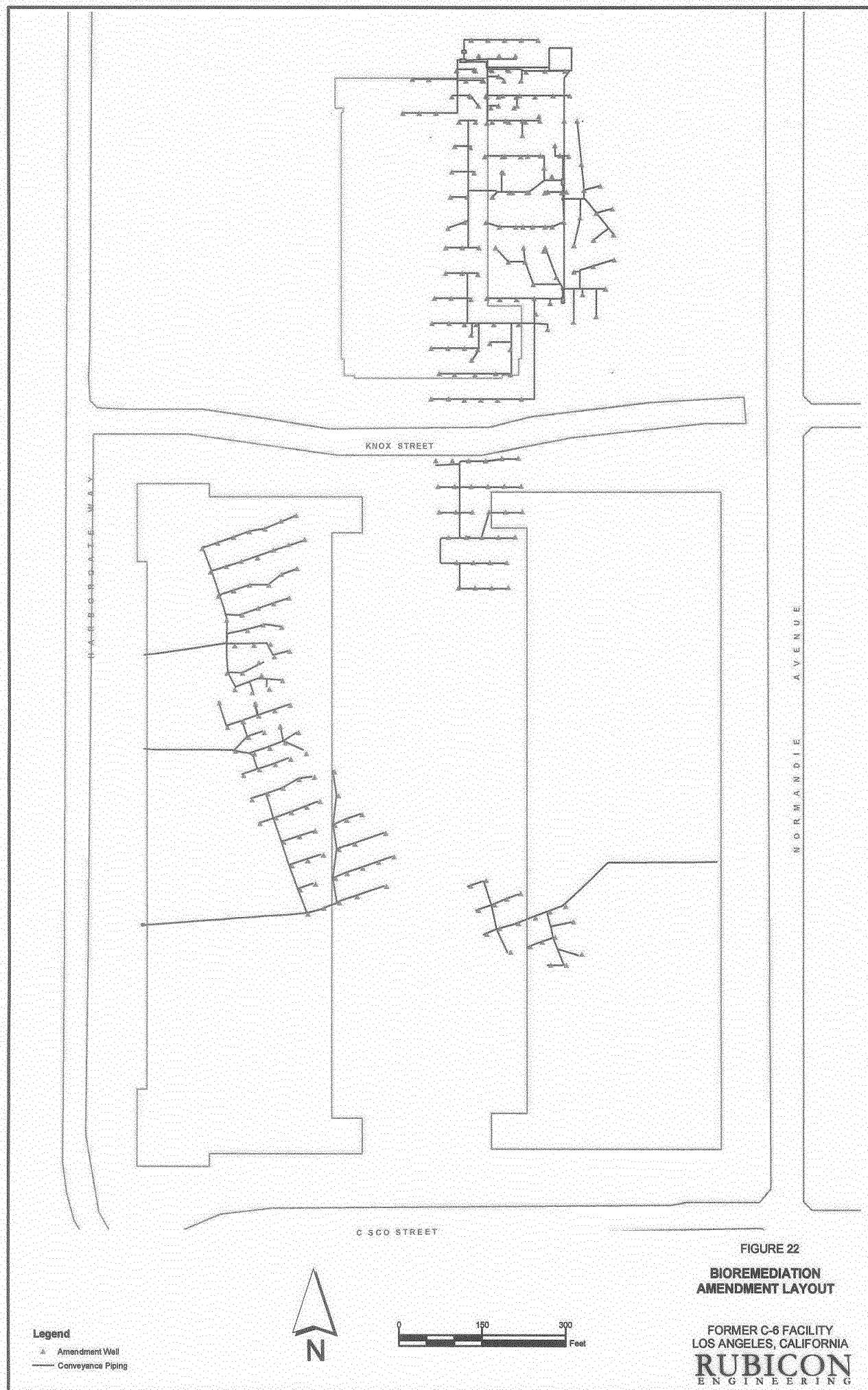
FIGURE 21

2004

SITE AND VICINITY PLUMES
GAGE AQUIFER

FORMER C-6 FACILITY
LOS ANGELES, CALIFORNIA

RUBICON
ENGINEERING



Legend

- ▲ Amendment Well
- Conveyance Piping

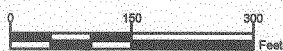
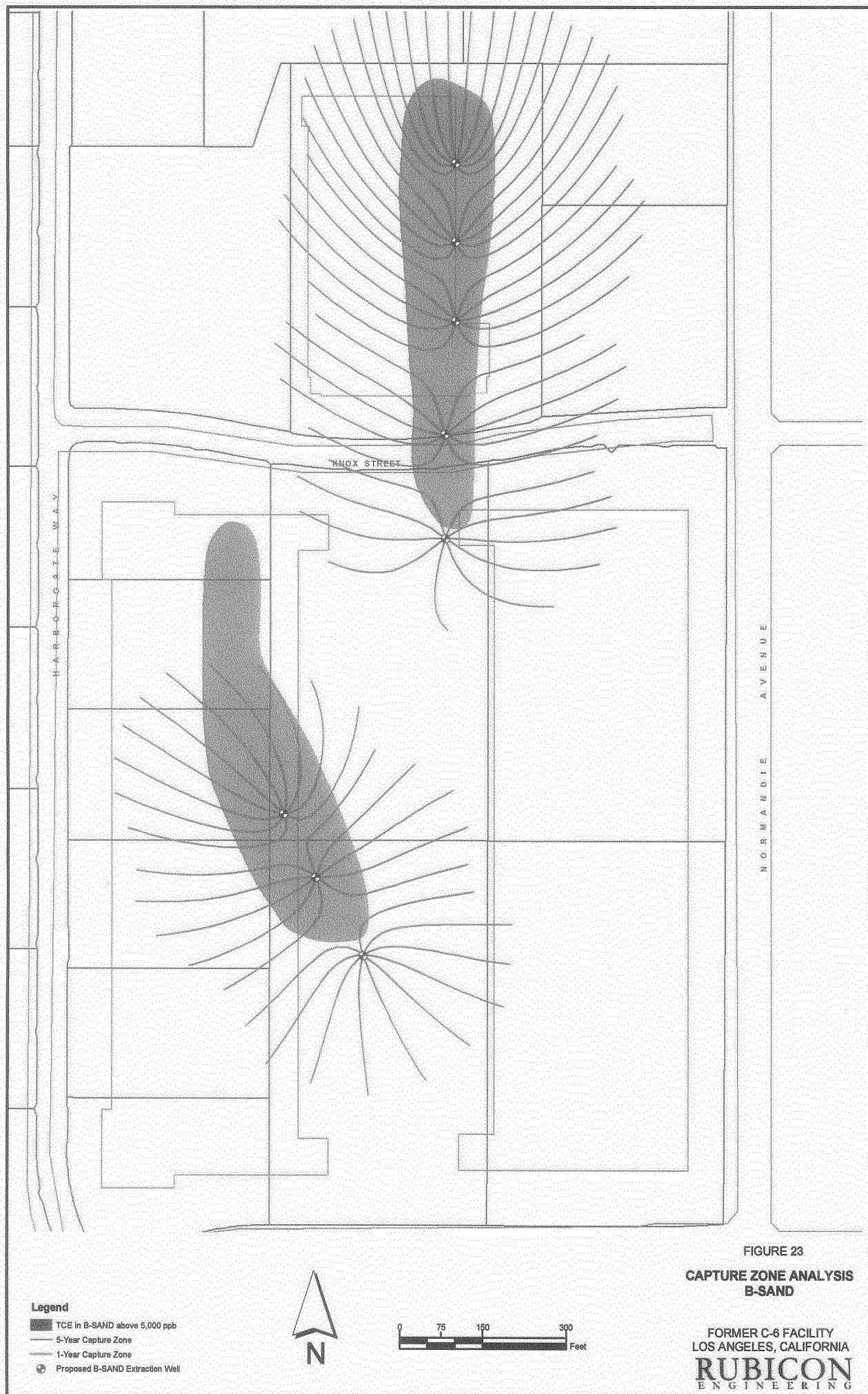
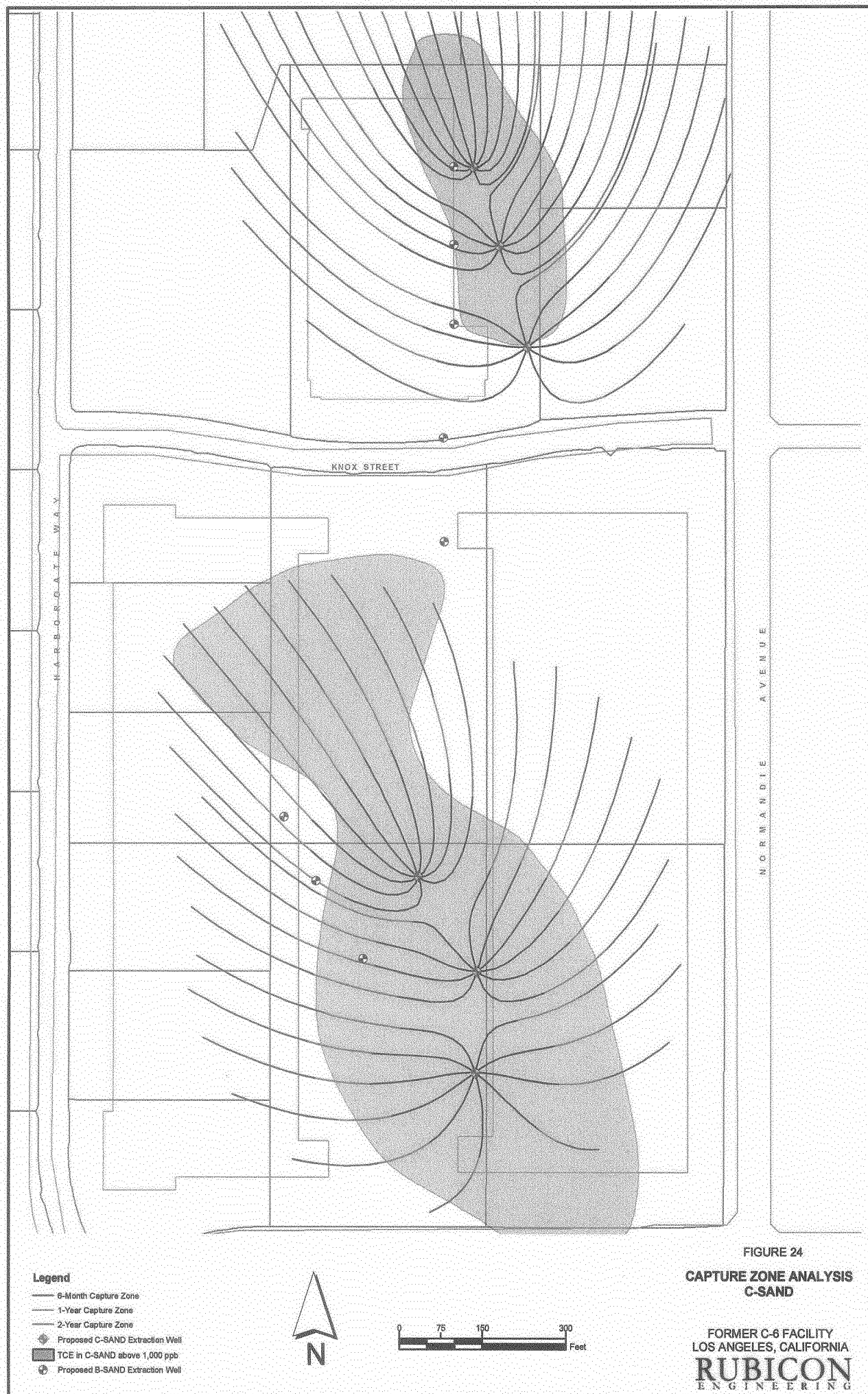


FIGURE 22

**BIOREMEDIATION
AMENDMENT LAYOUT**

FORMER C-6 FACILITY
LOS ANGELES, CALIFORNIA
RUBICON
ENGINEERING





Appendix A

Temporal Variations of TCE and 1,1-DCE

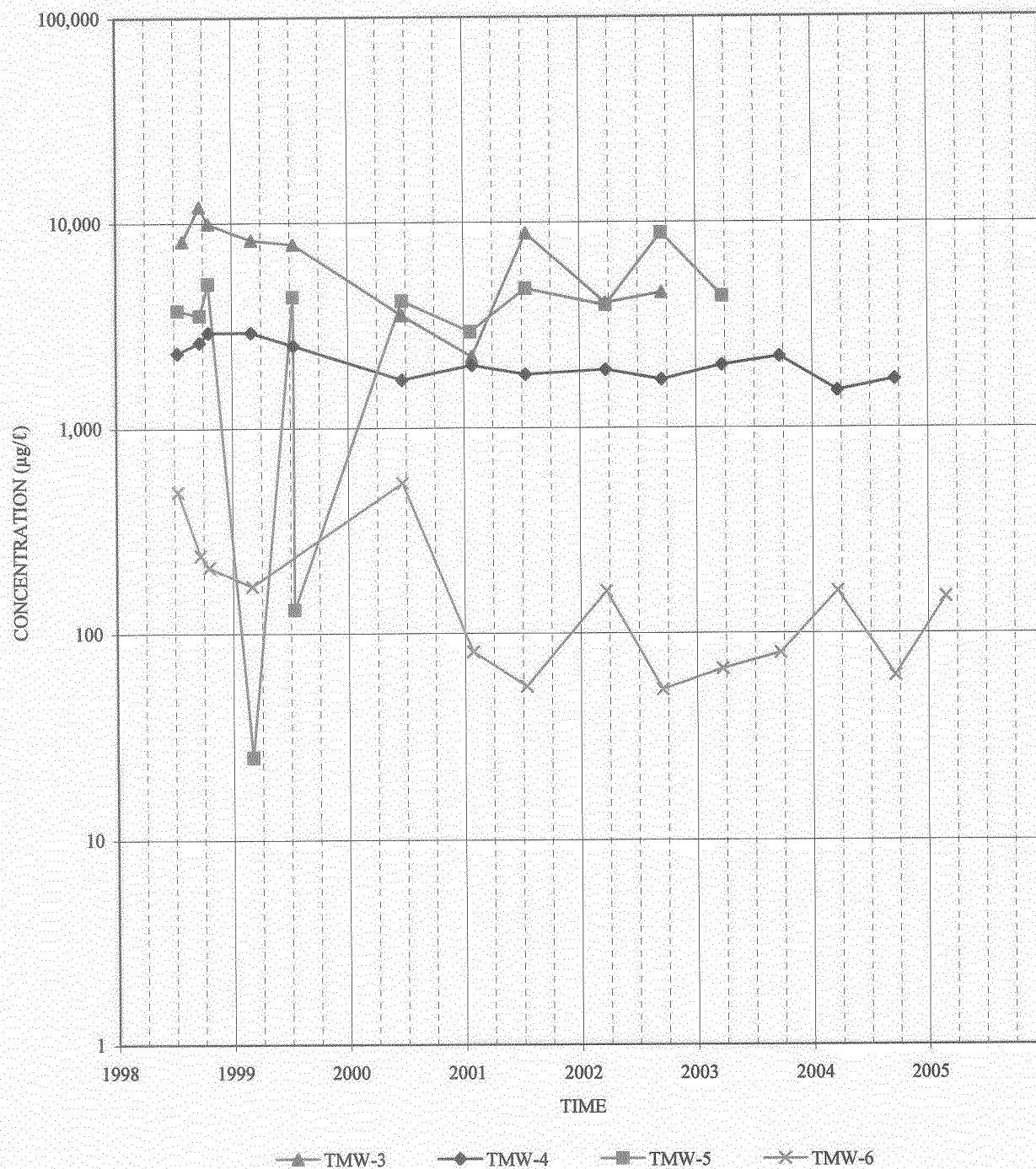


FIGURE A-1
 TEMPORAL VARIATION OF TCE
 CONCENTRATIONS IN
 GROUND WATER NEAR
 BUILDING 2
 BOEING REALTY CORPORATION
 FORMER C-6 FACILITY
 LOS ANGELES, CALIFORNIA
RUBICON
 ENGINEERING

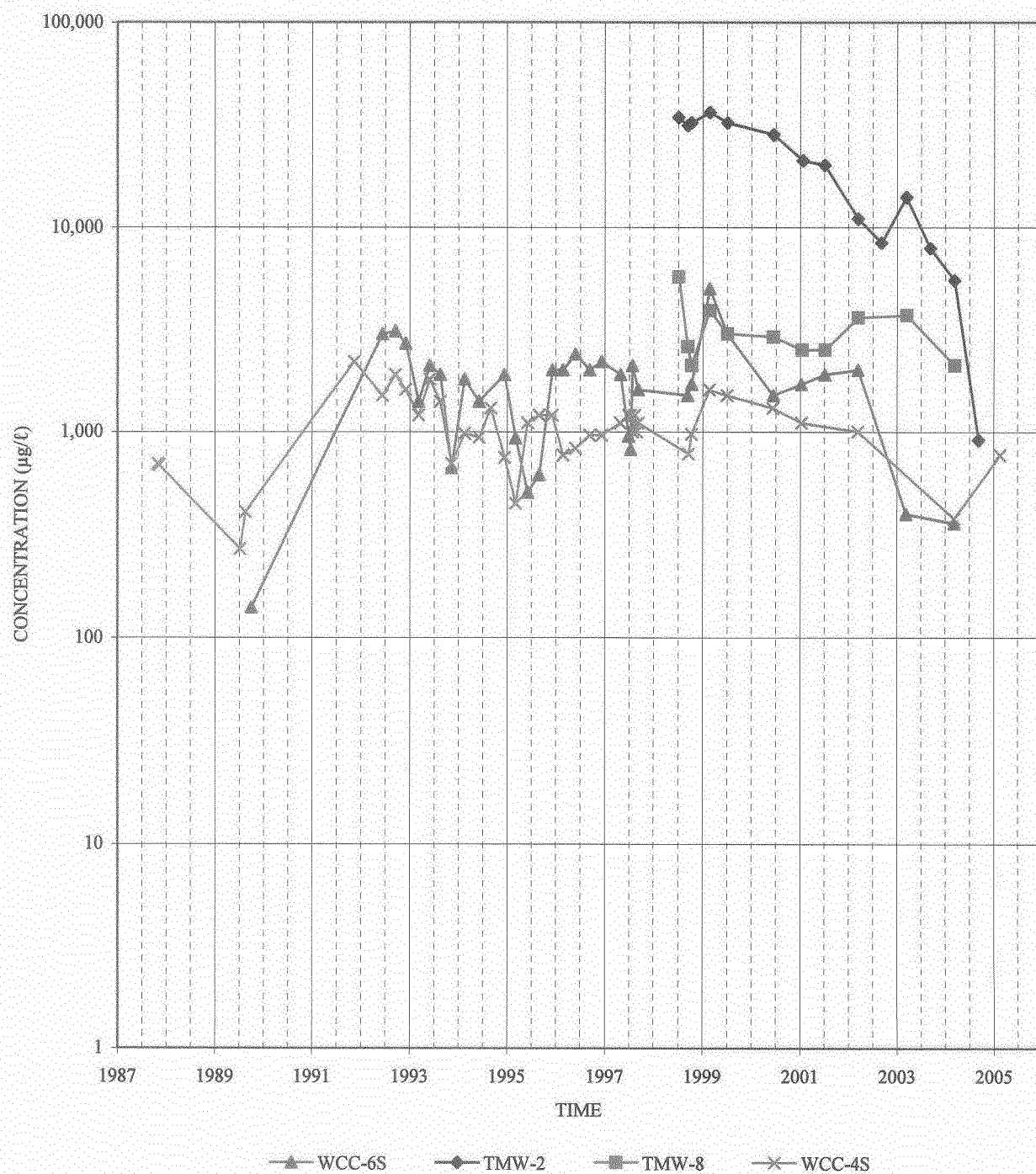


FIGURE A-2
 TEMPORAL VARIATION OF TCE
 CONCENTRATIONS IN
 GROUND WATER NEAR
 BUILDING 1/36
 BOEING REALTY CORPORATION
 FORMER C-6 FACILITY
 LOS ANGELES, CALIFORNIA

RUBICON
 ENGINEERING

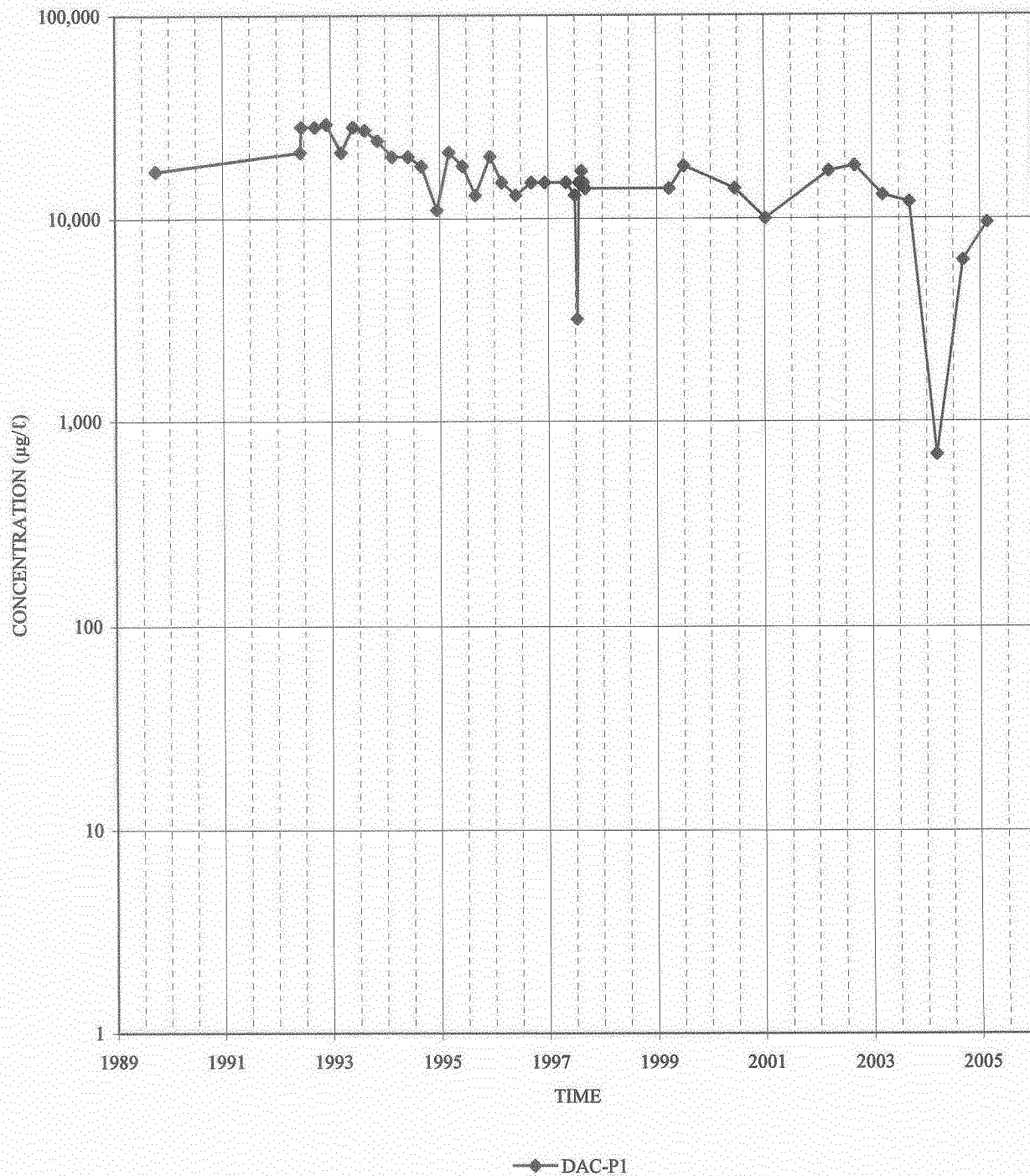


FIGURE A-3
 TEMPORAL VARIATION OF TCE
 CONCENTRATIONS IN
 GROUND WATER ALONG
 WESTERN SITE BOUNDARY
 BOEING REALTY CORPORATION
 FORMER C-6 FACILITY
 LOS ANGELES, CALIFORNIA
RUBICON
 ENGINEERING

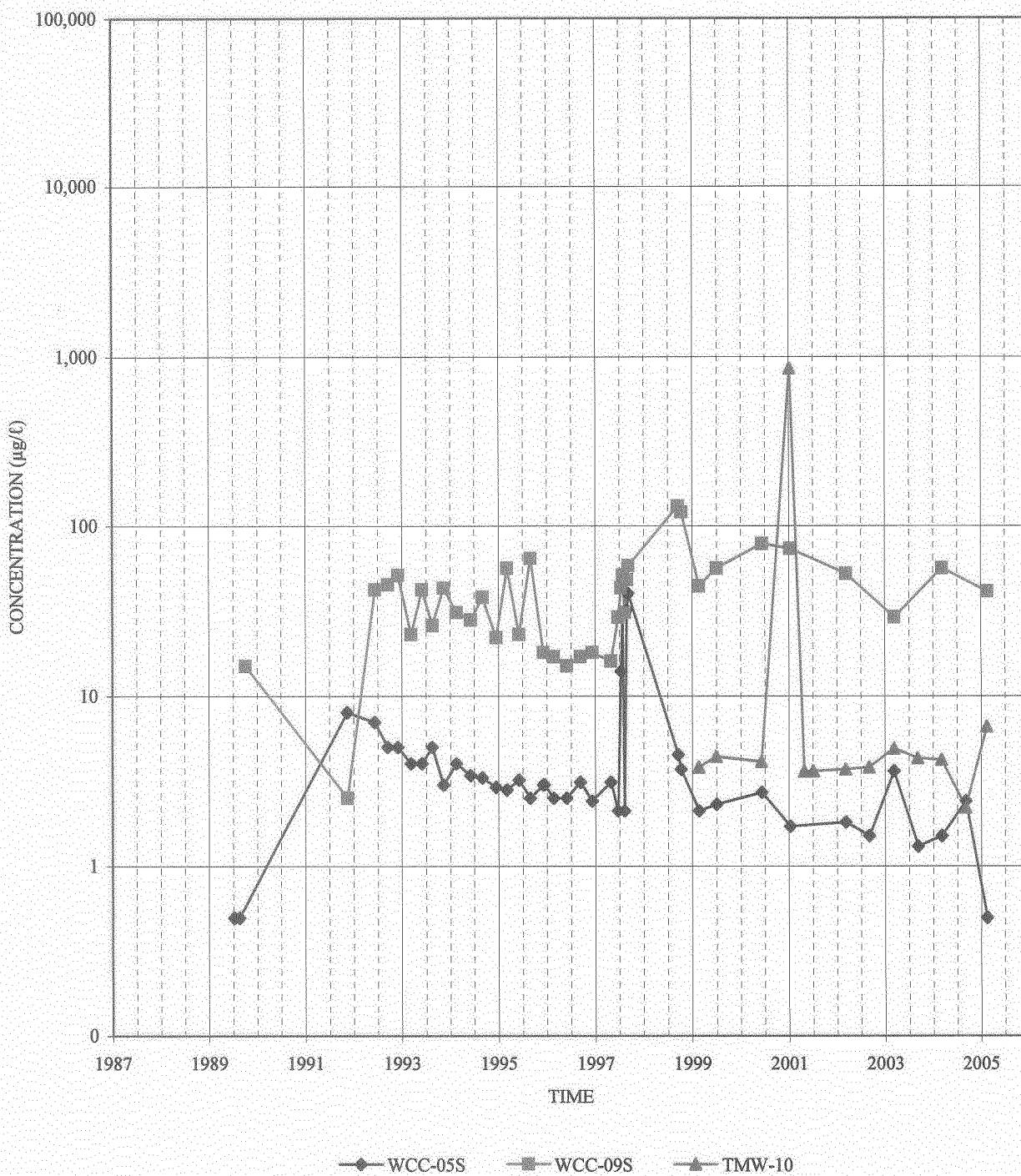


FIGURE A-4
 TEMPORAL VARIATION OF TCE
 CONCENTRATIONS IN
 GROUND WATER ALONG
 EASTERN SITE BOUNDARY
 BOEING REALTY CORPORATION
 FORMER C-6 FACILITY
 LOS ANGELES, CALIFORNIA

RUBICON
 ENGINEERING

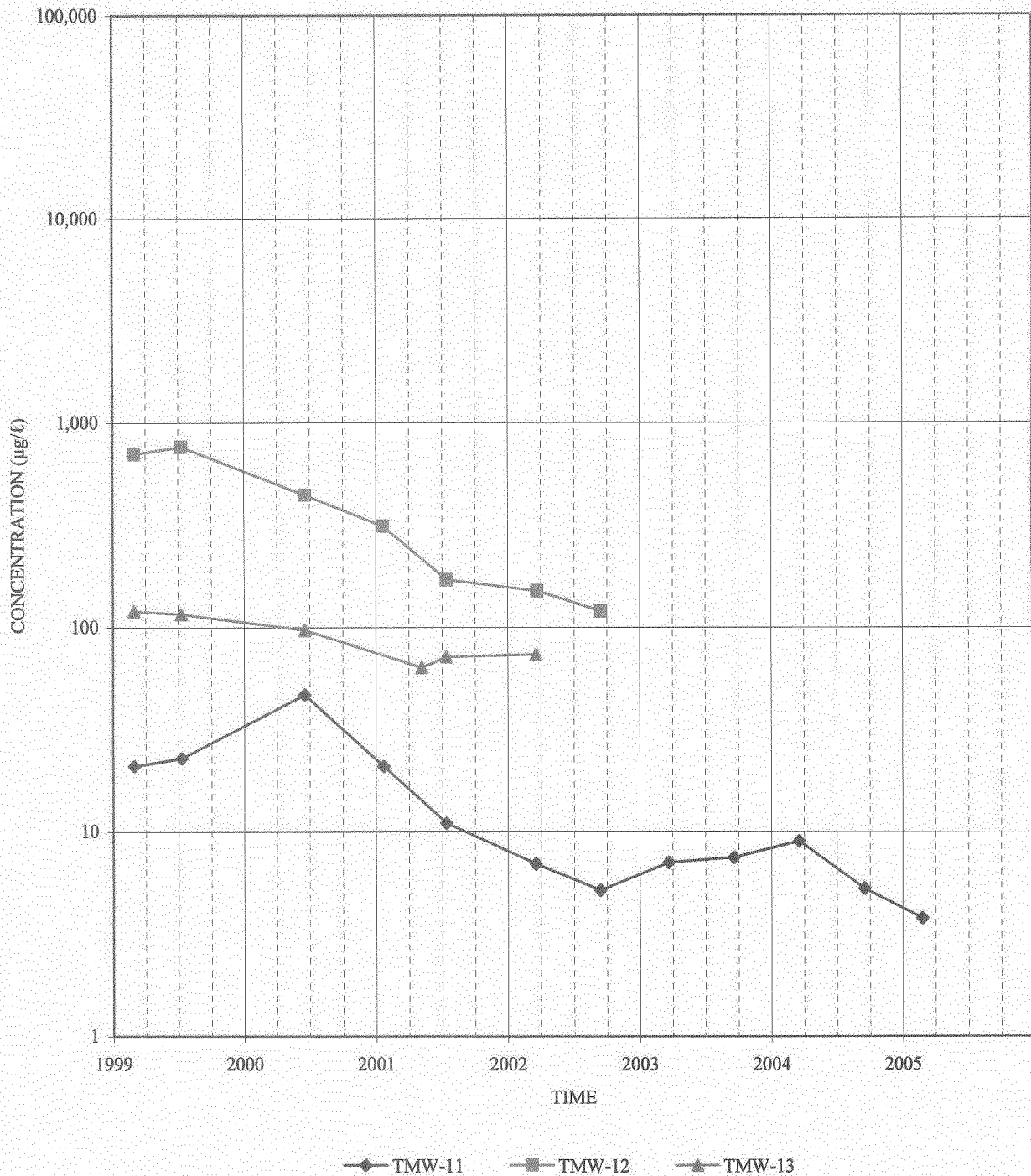


FIGURE A-5
 TEMPORAL VARIATION OF TCE
 CONCENTRATIONS IN
 GROUND WATER ALONG
 SOUTHERN SITE BOUNDARY
 BOEING REALTY CORPORATION
 FORMER C-6 FACILITY
 LOS ANGELES, CALIFORNIA

RUBICON
 ENGINEERING

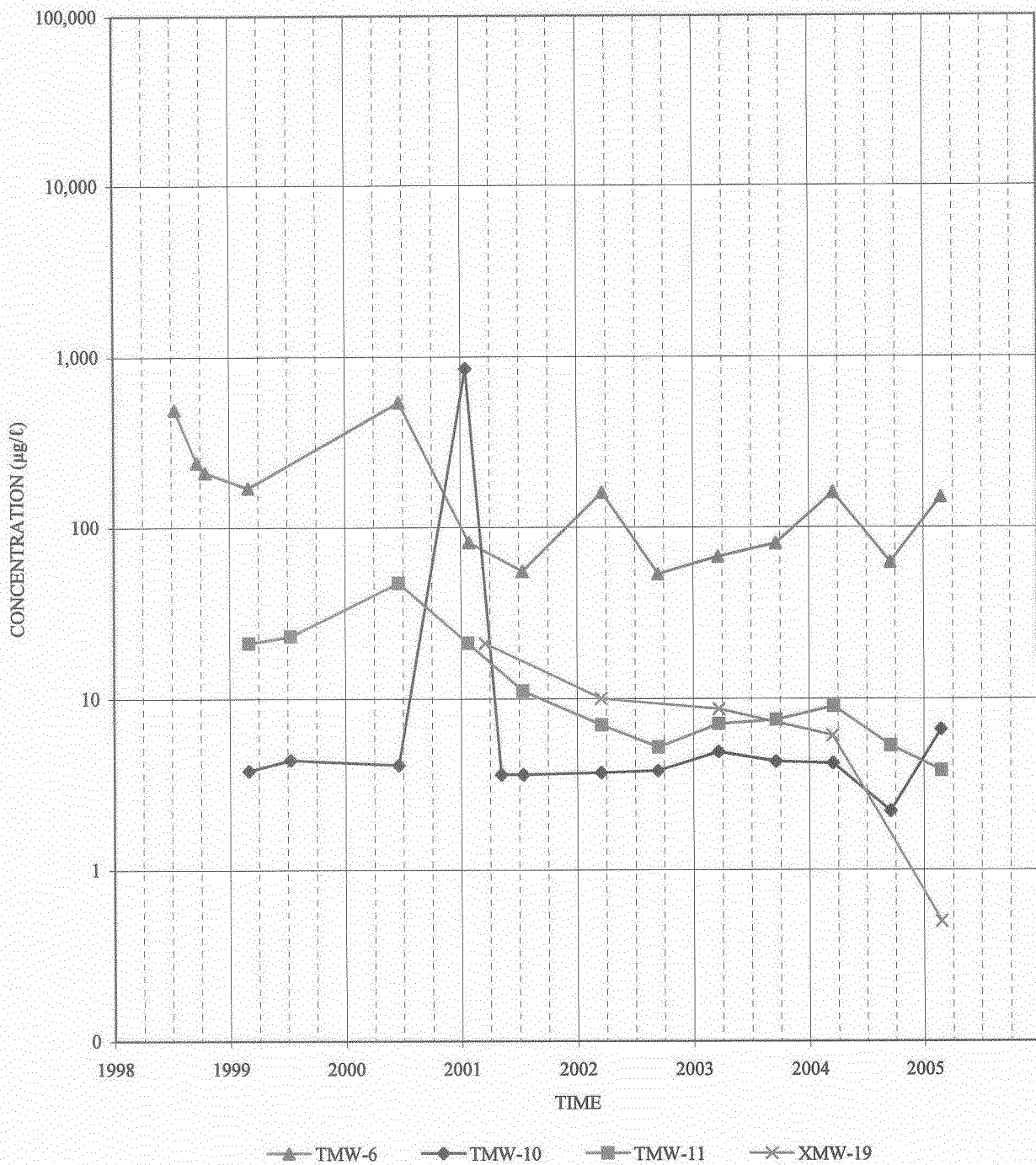


FIGURE A-6
 TEMPORAL VARIATION OF TCE
 CONCENTRATIONS IN
 GROUND WATER ALONG SOUTH-
 EASTERN SITE BOUNDARY
 BOEING REALTY CORPORATION
 FORMER C-6 FACILITY
 LOS ANGELES, CALIFORNIA

RUBICON
 ENGINEERING

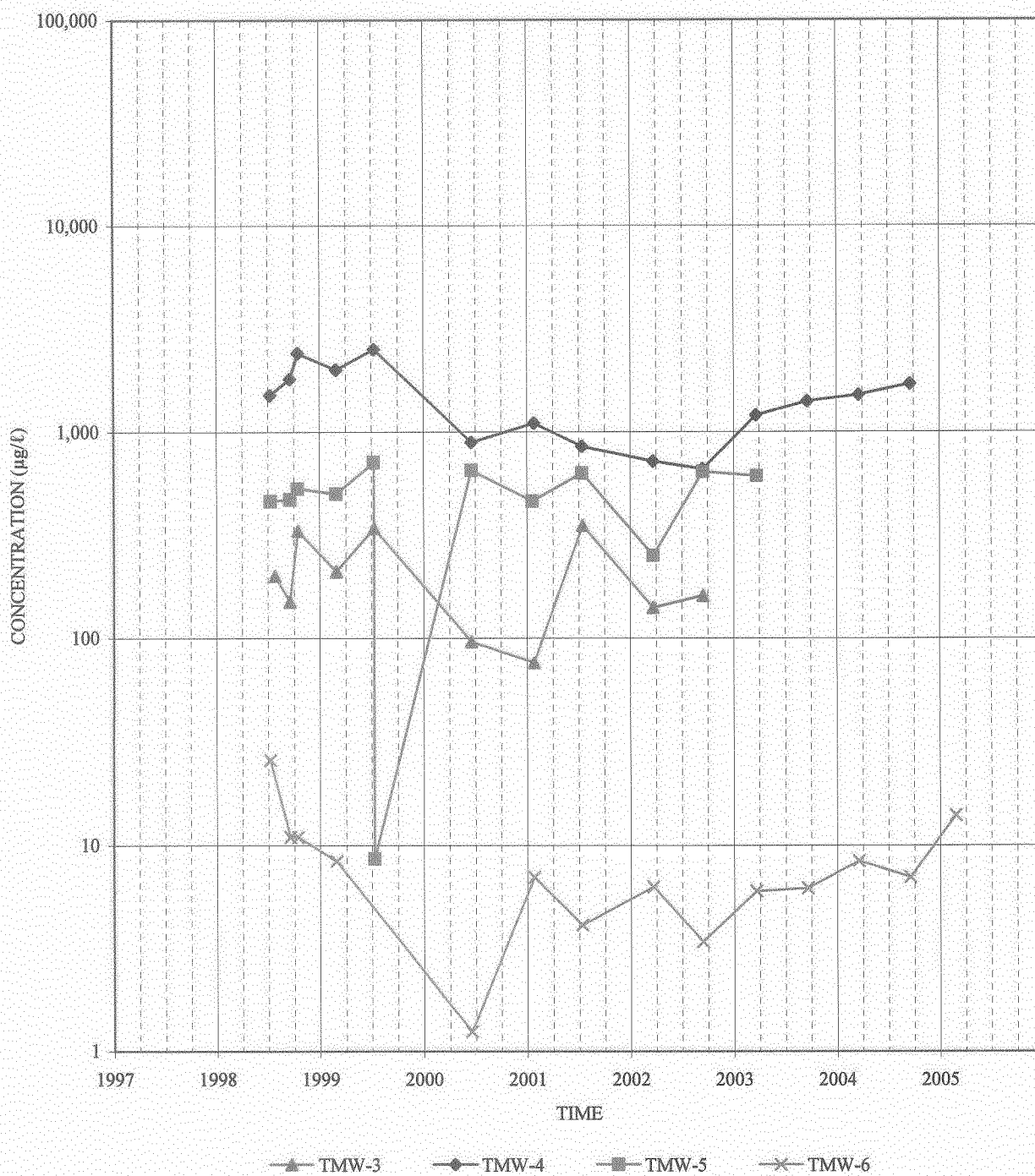


FIGURE A-7
 TEMPORAL VARIATION OF 1,1-DCE
 CONCENTRATIONS IN
 GROUND WATER NEAR
 BUILDING 2
 BOEING REALTY CORPORATION
 FORMER C-6 FACILITY
 LOS ANGELES, CALIFORNIA

RUBICON
 ENGINEERING

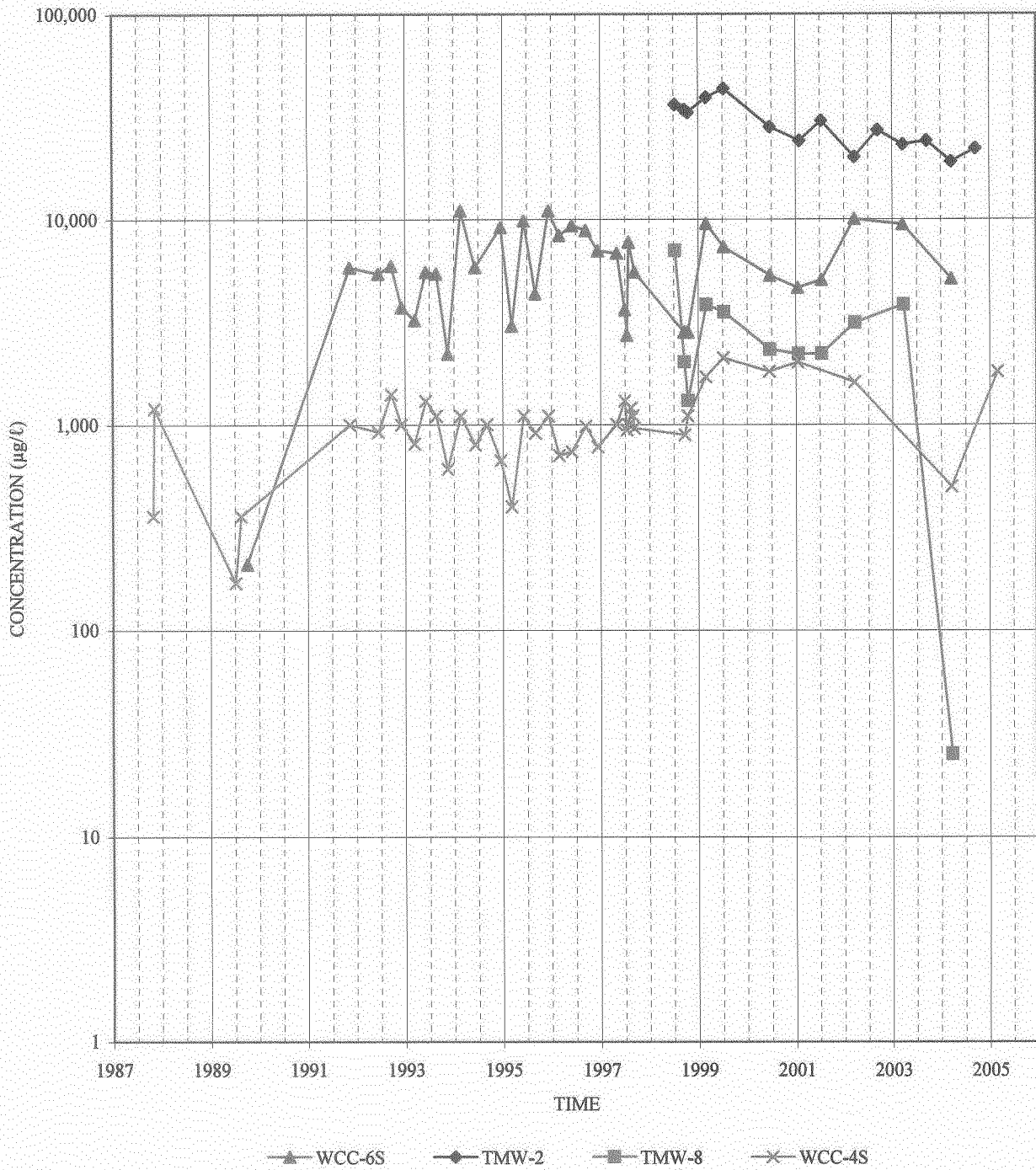


FIGURE A-8
 TEMPORAL VARIATION OF 1,1-DCE
 CONCENTRATIONS IN
 GROUND WATER NEAR
 BUILDING 1/36
 BOEING REALTY CORPORATION
 FORMER C-6 FACILITY
 LOS ANGELES, CALIFORNIA

RUBICON
 ENGINEERING

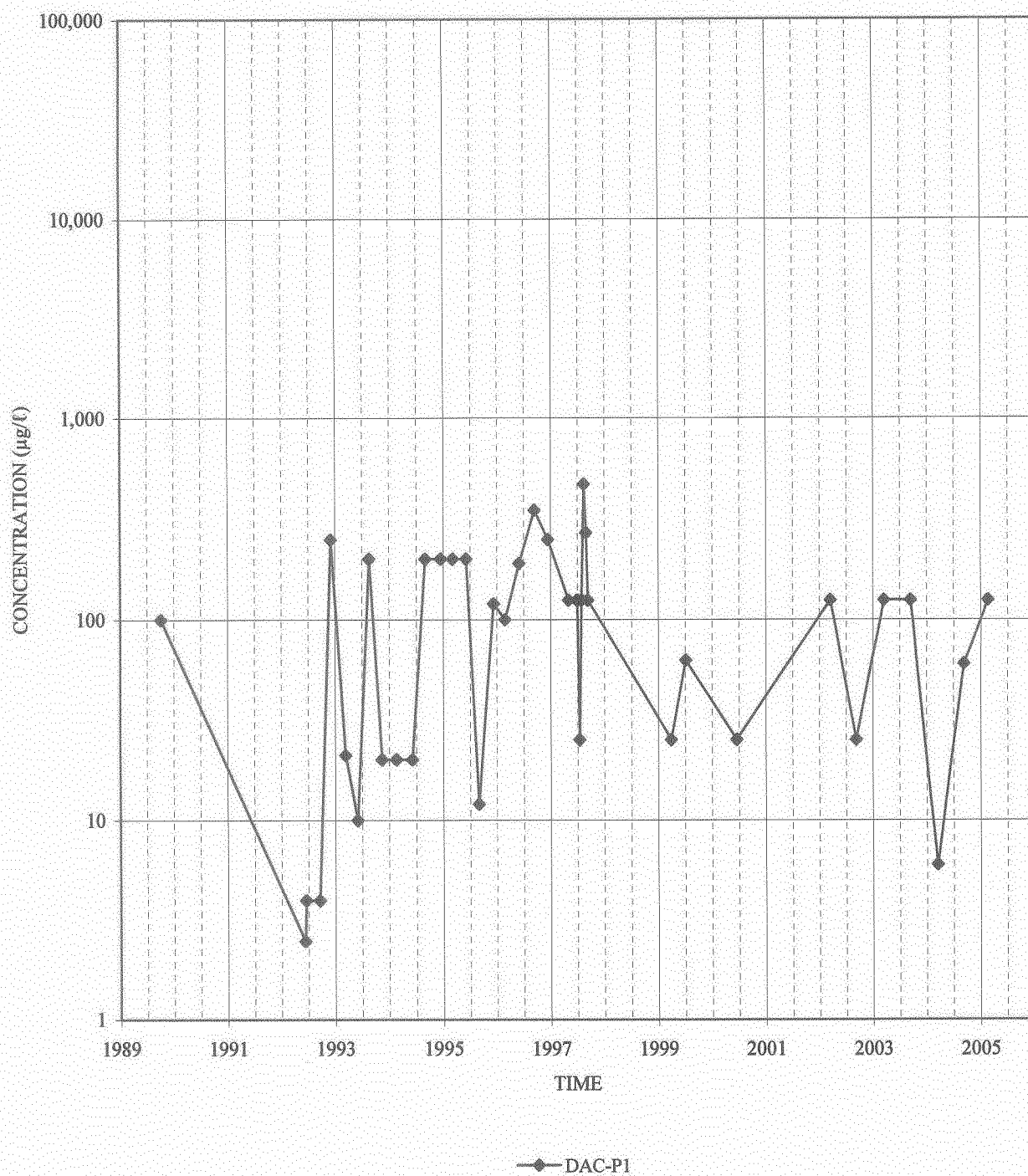


FIGURE A-9
 TEMPORAL VARIATION OF 1,1-DCE
 CONCENTRATIONS IN
 GROUND WATER ALONG
 WESTERN SITE BOUNDARY
 BOEING REALTY CORPORATION
 FORMER C-6 FACILITY
 LOS ANGELES, CALIFORNIA
RUBICON
 ENGINEERING



FIGURE A-10
 TEMPORAL VARIATION OF 1,1-DCE
 CONCENTRATIONS IN
 GROUND WATER ALONG
 EASTERN SITE BOUNDARY
 BOEING REALTY CORPORATION
 FORMER C-6 FACILITY
 LOS ANGELES, CALIFORNIA

RUBICON
 ENGINEERING

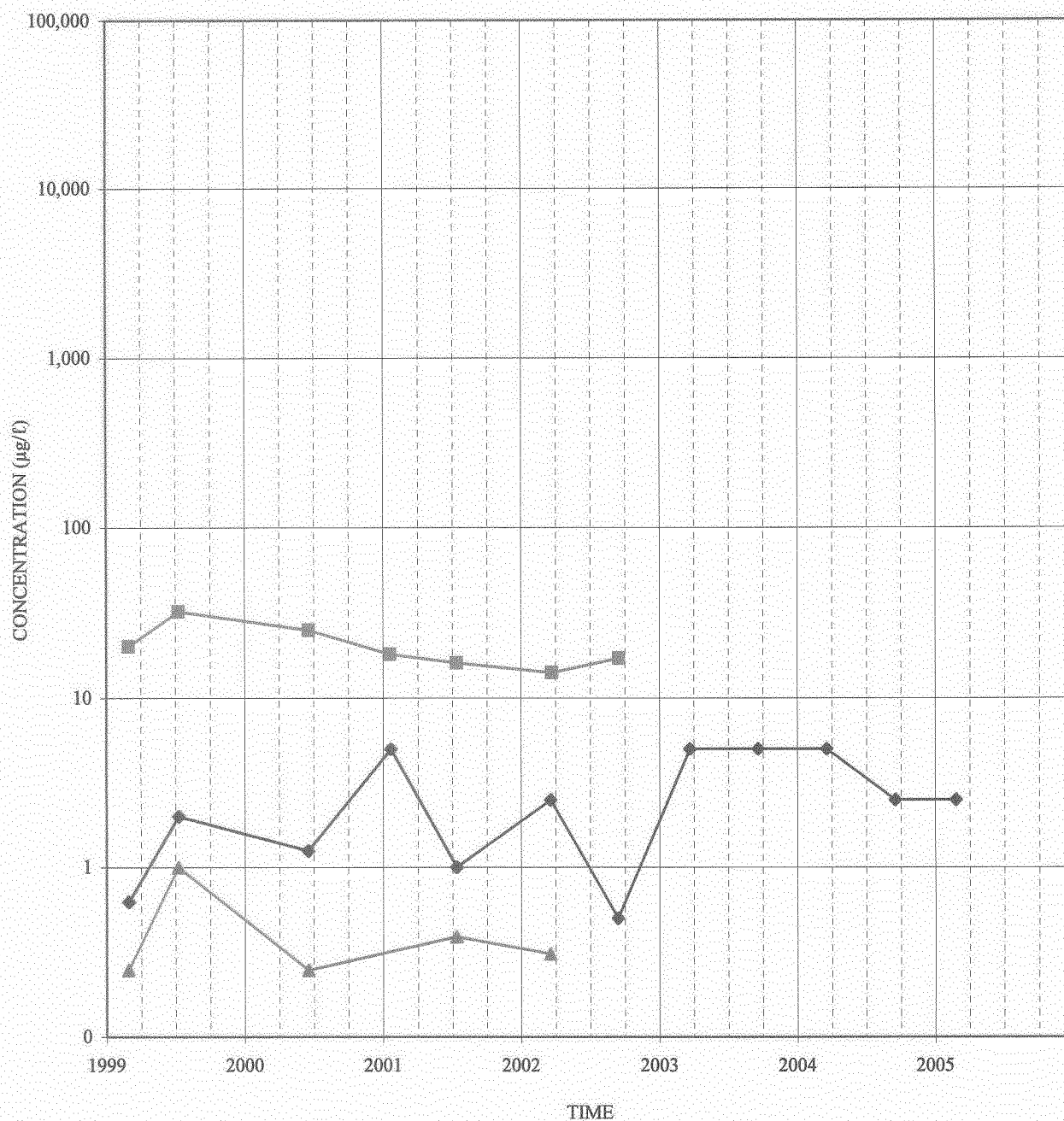


FIGURE A-11
 TEMPORAL VARIATION OF 1,1-DCE
 CONCENTRATIONS IN
 GROUND WATER ALONG
 SOUTHERN SITE BOUNDARY
 BOEING REALTY CORPORATION
 FORMER C-6 FACILITY
 LOS ANGELES, CALIFORNIA

RUBICON
 ENGINEERING

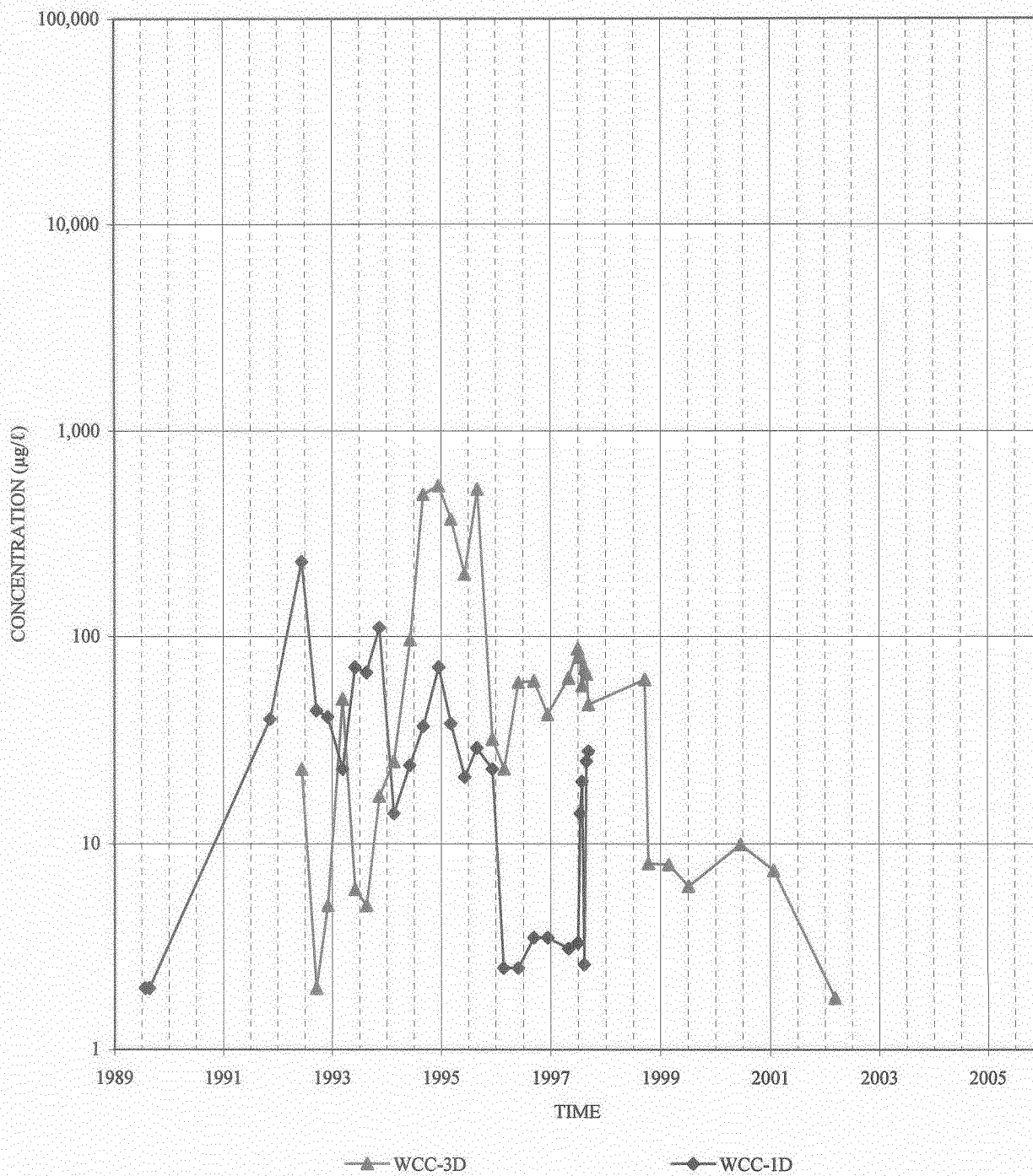


FIGURE A-12
**TEMPORAL VARIATION OF TCE
 CONCENTRATIONS IN
 C-SAND GROUND WATER NEAR
 BUILDING 1/36**
 BOEING REALTY CORPORATION
 FORMER C-6 FACILITY
 LOS ANGELES, CALIFORNIA
RUBICON
 ENGINEERING

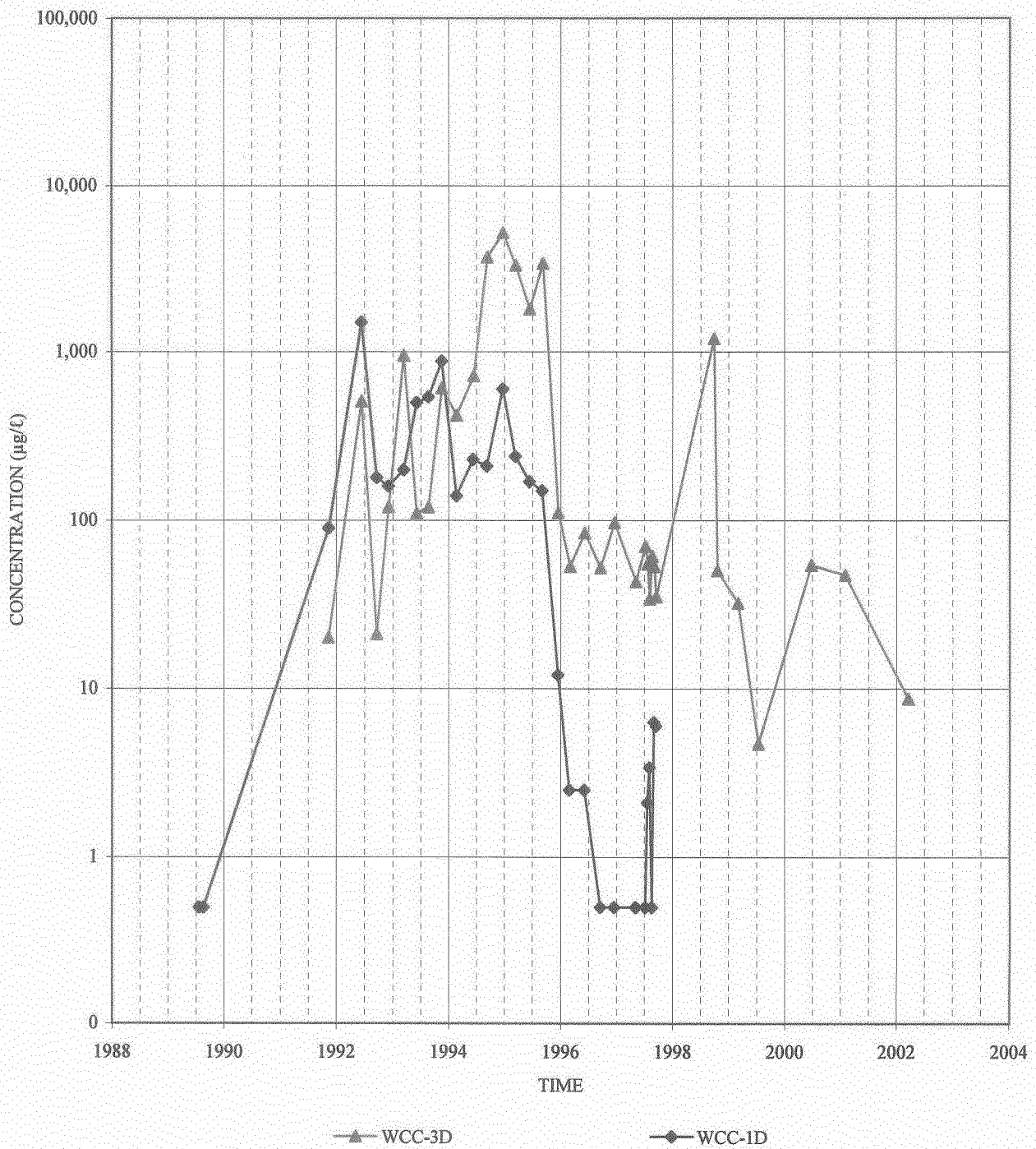


FIGURE A-13
 TEMPORAL VARIATION OF 1,1-DCE
 CONCENTRATIONS IN
 C-SAND GROUND WATER NEAR
 BUILDING 1/36
 BOEING REALTY CORPORATION
 FORMER C-6 FACILITY
 LOS ANGELES, CALIFORNIA
RUBICON
 ENGINEERING